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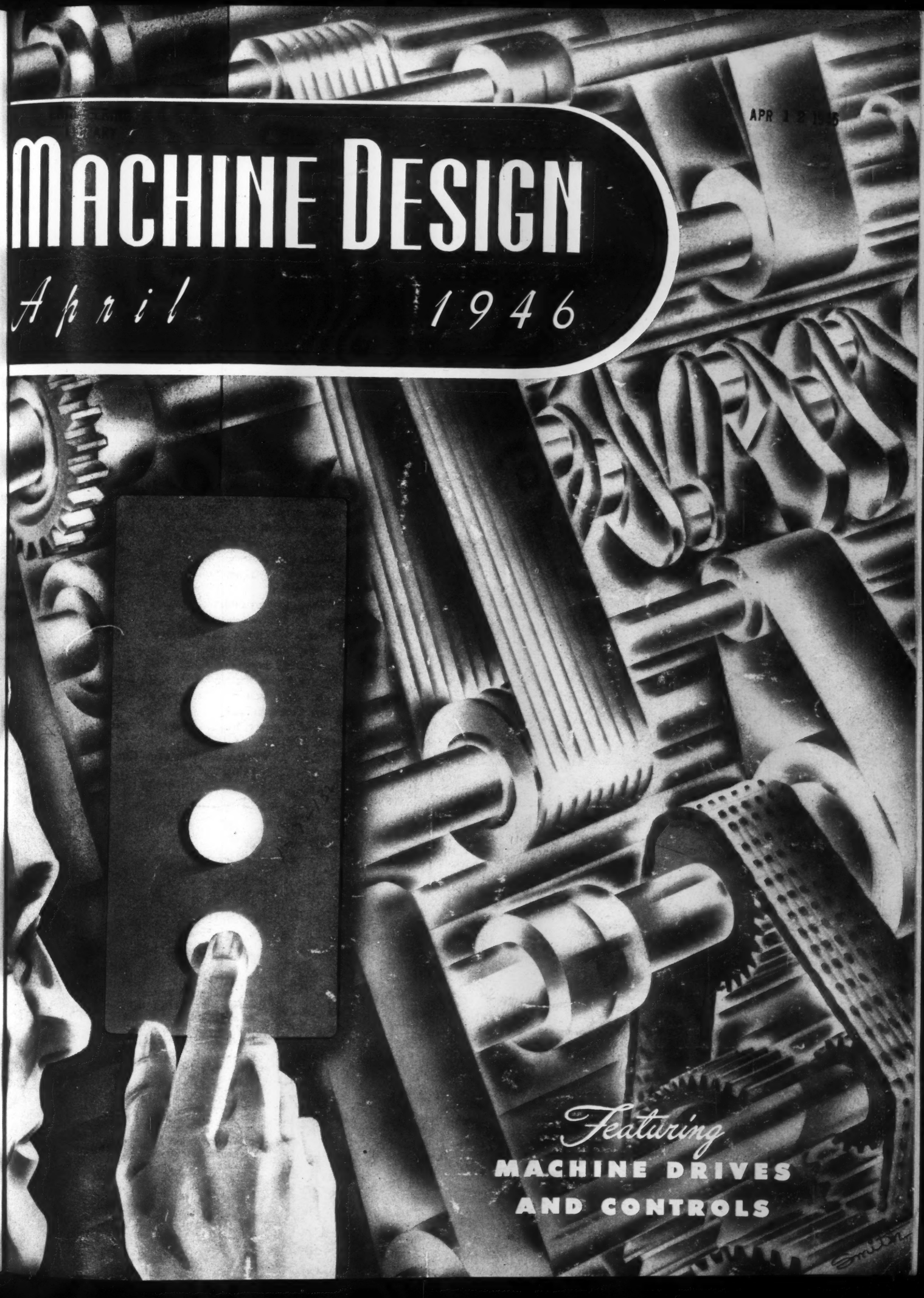
MACHINE DESIGN

April 1946



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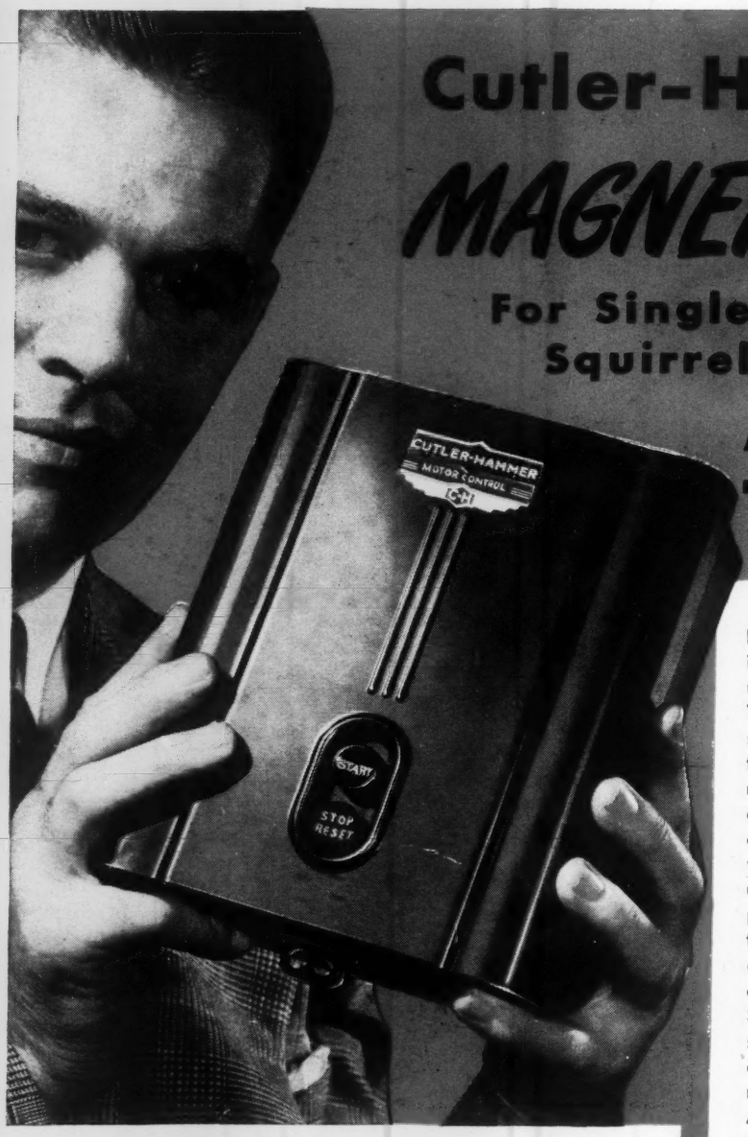

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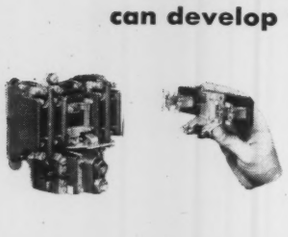

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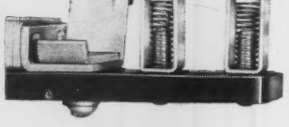

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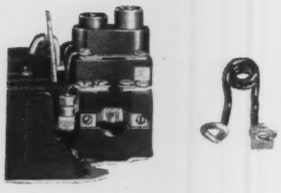

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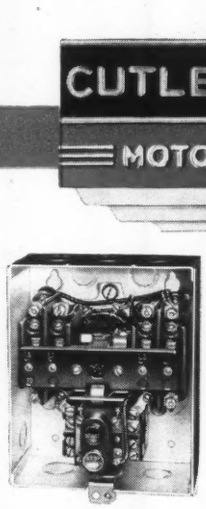

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The C-H 9586 Starter is available in all standard constructions, with or without pushbuttons in case, with transfer switch, in combination starter, and in skeleton construction for built-in application.

MACHINE DESIGN

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CONTENTS

April, 1946

Volume 18 Number 4

Machine Drives and Controls Issue

Itemized Index 7

Topics 98

Special Machine Utilizes Combination Drives 101
By F. J. Kampmeier

Pneumatic Power and Control—Where They Fit 107
By Robert E. Becker

Engineers' Symposium 113
By L. A. Elmer, J. S. Baker, S. J. Deitz, F. Rumble, E. C. Denne, D. A. Rogers, J. H. McCormick

Are High Speeds Required? Investigate High-Cycle Motors! 121
By Marion B. Sawyer

Trend in Automotive Transmissions—Part I 127
By Colin Carmichael

Novel Reciprocating Drive Gives Harmonic Motion 133

Atomic Power in Peacetime 136
By C. G. Suits

Electronics Actuates Tracer Control 137
By R. F. Helmkamp

Machine Hydraulic—Part 1—Throttle Circuits 143
By Albert H. Dall

What's Behind Airborne Radar?—Part II—Control of Scanners 149
By Donald M. Skidmore and Charles R. Chambers

Matching the Small Motor to the Job 155
By le Moyne Dabbs

Control Diagrams—an Aid to Design 159
By F. L. Fisher

Toward More Automatic Control! (Editorial) 165

Assets to a Bookcase 166

Production Processes—Part X—Roll Forming 167
By Roger W. Bolz

Design Opportunities in Fastener Assemblies 173
By W. M. Hanneman

Nickel, Wrought and Cast (Materials Work Sheet) 175

Applications—of Engineering Parts, Materials and Processes 180

New Parts, Materials and Equipment 182

Men of Machines 194

Business and Sales Briefs 200

Calendar of Meetings 208

New Machines 210

Helpful Literature 355

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Special Machine Utilizes Combination Drives

By F. J. Kampmeier
Chief Engineer
The Ingersoll Milling Machine Co., Rockford, Ill.

SPECIAL-PURPOSE machines for producing parts of intricate shape involve all the ingenuity the designer can command, especially when the machine must be readily adjustable to accommodate a large number of variations in different combinations. In such a machine, the design of the various drives and controls requires a thorough knowledge of the advantages and limitations of electrical, hydraulic and mechanical power. All three of these methods are combined for the operation of the milling machine, illustrated above, which was designed to produce cutter bits for the Reed Roller Bit Co., Houston, Texas. Used in clusters on the ends of rotary rock drills, these particular bits vary considerably in design to

fit the peculiar geological formations in which they are to drill.

One of the features of the bit is that it has a double conical spiral thread in which teeth are cut. The large end always contains a regularly spaced series of teeth which may be parallel to or skewed in relation to the axis of the roller bit. Previously, the teeth were milled through the conical section in much the same way teeth are cut in a bevel gear. This resulted in a short, small tooth on the small end of the roller and a long, large tooth on the large end. For certain formations, however, it is desired to have teeth of constant size on the conical helix. Producing such a design on a single-spindle end milling machine would be laborious and costly.

The problem, therefore, was to design a machine capable of milling a constant length of tooth in the conical helix, removing the thread runout at the large end and milling the regularly spaced teeth at the large end. The machine had to be sufficiently flexible so that the cone angle, the pitch of the teeth, the amount of skew, the depth of cut, the pitch of the spiral, and several other features could be changed to suit the particular requirements for any rock drilling operation. Furthermore, it was required that the machine be quickly changeable from one setup to another and economically profitable when used on relatively small lots.

It was anticipated that the machine would be operated by women, so controls had to be designed in such manner as to permit easily performed manual operations with power actuation for most of the adjustments and all clamping devices, thus minimizing operator fatigue. Also, it was considered desirable to use a sample bit as a master and duplicate it in multiple on the machine.

Hydraulic and mechanical drives are utilized in this 10-spindle milling machine, the indexing and cross feed of which employ a unique combination of mechanical and hydraulic actions. Indexing is automatic, a tracer mechanism actuating a switch whenever a tooth is in position. The machine cycle is terminated by a counter which is preset to the number of teeth in each bit design.

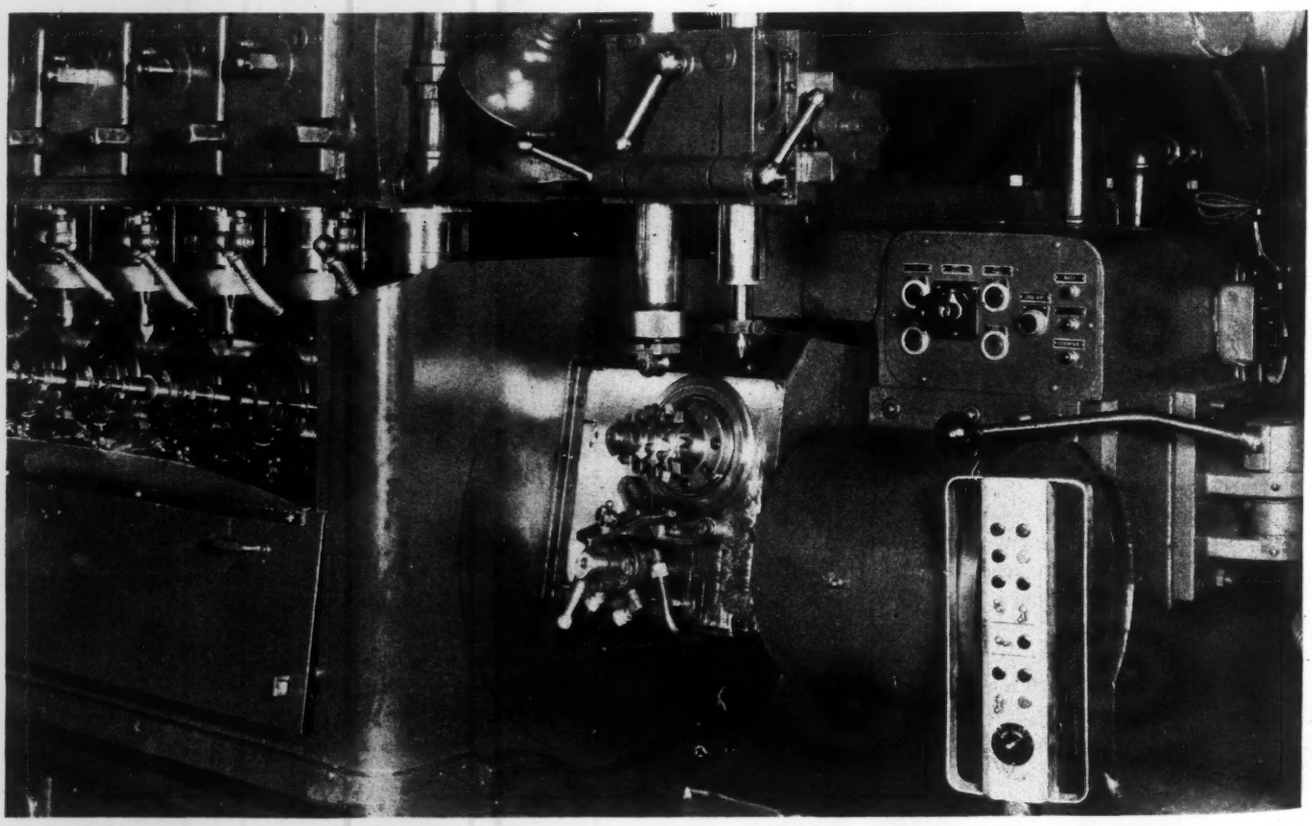
Tracer Indexes Workpiece

Shown in *Fig.* 1 is a master bit in position on its spindle with the tracer mechanism in the retracted position. When indexing automatically the tracer with the roller head is lowered to contact the master. As it traces over the helix it drops between the teeth for successive indexing until the counter terminates the cycle. This counter is actuated electrically by the feed action of the hydraulic cross-feed cylinder as each cut is completed.

The cutter head and the tracer mechanism are advanced by lead gears and screws as the workpieces are indexed to compensate for the spiral lead on the workpiece. Cross feed of the cutters is accomplished through the travel of the cutter head by means of a hydraulic cylinder. For this reason the tracer wheel is mounted on a cross slide to allow for the cutter head travel. Features of these head movements will be discussed later.

Design details of the tracer are shown in cross section in *Fig.* 2. When the tracer wheel drops, a precision switch

Fig. 1—Sample workpiece is used as a master. Tracer mechanism indexes the work spindles so that cutters duplicate teeth on the workpieces



in the upper end of the mechanism is actuated by a rod, causing the work spindles to be locked in position and allowing the cutters to feed forward and back. Indexing is then resumed until the wheel drops between the next two teeth.

However, if the indexing wheel should strike any obstacle in its path it would flex at the ball joint shown above the wheel. This action would operate a safety limit switch, opening the feed circuits, raising cutters out of the work, and stopping the machine. The second tracer with the stylus head is employed for manual operation of the machine when the helix runout at the large end of the workpiece is removed. Operation of this tracer is similar except that the machine does not index. A stylus corresponding in shape to the cutter tools is employed for this operation, the stylus being readily removable.

Referring to the work index and the cross feed of the cutter spindles previously mentioned, this drive is shown schematically in *Fig.* 3. The main drive for this operation as well as for indexing the cutter head and work spindles is a 5-horsepower, d-c motor, electronically controlled to give a 20:1 speed range (motor speeds between 90 and 1800 rpm). This motor indexes the work spindles through worm and gear drives as shown. The flexibility of electronic control permits indexing in minimum time and, in addition, provides a variable feed when removing the thread runout on the large end of the helix. A solenoid brake, mounted on the motor shaft, eliminates any tendency for the system to overtravel.

Cross Feed Employs Unique Power Screw

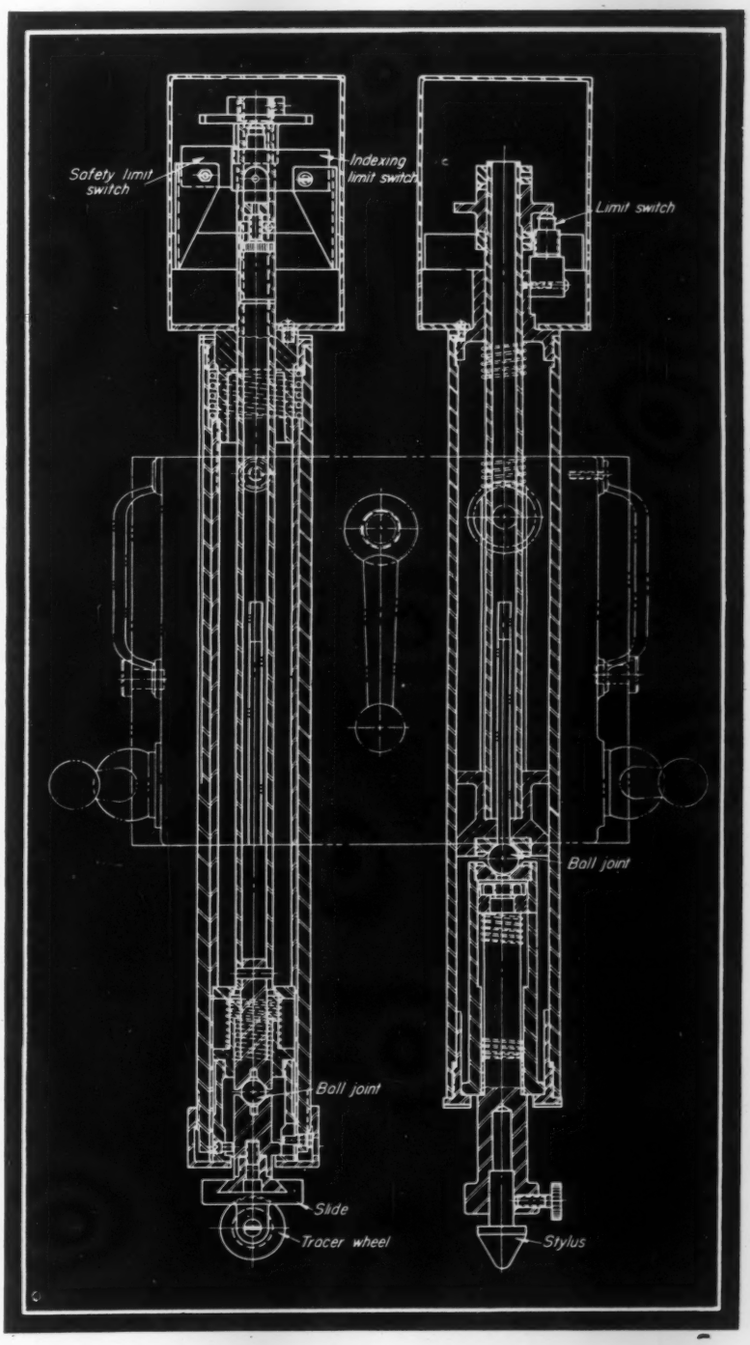
For indexing the cutter head, proper lead gears are chosen to match the helix feed on the workpiece. After each indexing has placed all the workpieces in cutting position, the head-feed cylinder feeds the cutting tools through the workpieces and back to their original position. Indexing and feed is obtained through the unique rack, screw and gear arrangement shown. One rack drive is located at each side of the head, beneath the head ways, to keep its movement uniform and minimize side thrust.

Quick adjustment of the cutter head when setting up the machine is provided by a two-speed 5-horsepower motor at a speed of 600 or 1800 rpm. This allows for making any adjustment required for positioning the teeth on the workpiece with respect to its helix. To initially position the head in proper relation with the workspindles, a double-jaw clutch is utilized so that the motor may position the cutter head without driving the work spindles. When the head is properly located with respect to the position of the helix, the clutch is re-engaged in its original position, disconnecting the adjusting motor and its train of gears as indicated in *Fig.* 3.

In *Fig.* 4 is shown the hydraulic circuit. Each time the work spindles are indexed they are locked for the duration of the cutter cross-feed cycle by hydraulically actuated brakes. Each brake locks two adjacent spindles so that five brakes are used for the ten work spindles. Because no cutting action takes place on the master spindle no braking effort is required for it.

Cutter spindle drive is also indicated schematically in *Fig.* 3;

Fig. 2—Tracer mechanism actuates precision switches for indexing cycle. Should tracer hit an obstruction, deflection at ball joint operates switch to stop the machine



these spindles are powered by a 3-speed, 20-horsepower motor, having speeds of 900, 1200 and 1800 rpm. The drive is through multiple V-belts to a shaft having five sets of bevel gears, each set driving two spindles through spur gears. Because the cutters are of the 2-lip type a flywheel is utilized on the main drive shaft and on each cutter spindle to provide inertia for the system in order that the cutting speed may be more uniform.

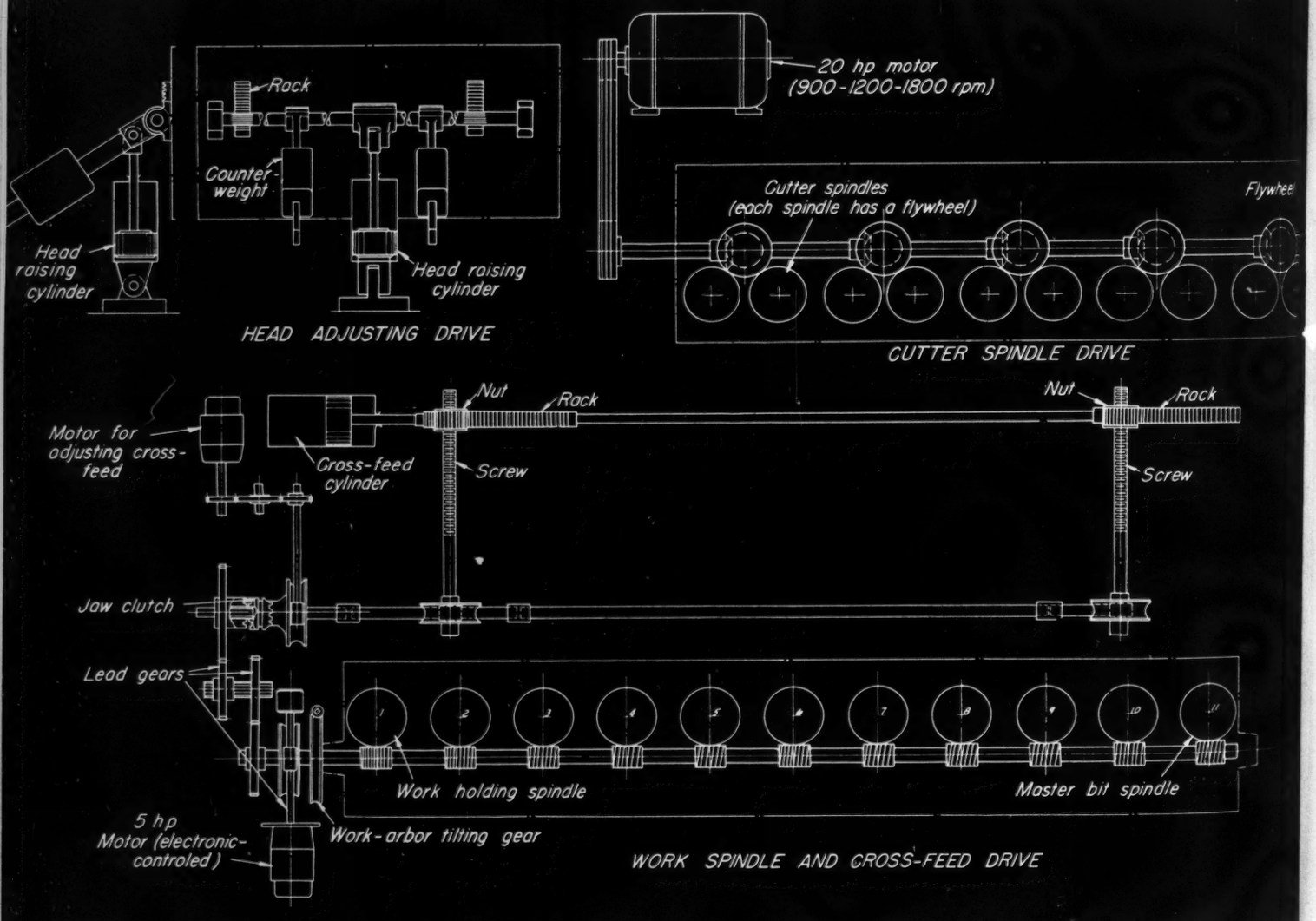
In setting up the machine the cutter head may be raised or lowered (for different size workpieces) by the hydraulic arrangement shown in *Fig.* 3. Operating an arm, keyed to a counterweighted shaft with a rack and pinion at each end, the cylinder readily adjusts the head to the height required. It is then locked in position by two cylinders, clamping the head to its vertical ways as indicated in *Fig.* 4.

Several of the work spindles and their cutter spindles are shown in the closeup view in *Fig.* 5. The spindles have C-washers for holding the workpieces to them. Hydraulic pressure from cylinders in the rear of these spindles lock the workpieces in position. This arrangement is shown in the cross-sectional view of *Fig.* 6. Pull of the piston spreads wedge rings against the inside walls of the workpiece in relation to the compression exerted on a spring. The remaining force exerted by the piston holds the work against a serrated shoulder on the mandrel.

Rotating Piston Simplifies Design

An unusual application of hydraulic cylinders is possible in this design because of the slow rotational speed of the work spindle. Although the cylinder remains stationary, the piston revolves with the workpiece, simplifying the design and obviating a high-pressure thrust bearing

Fig. 3—Schematic drives for head, cutter spindles, indexing and cutter cross feed



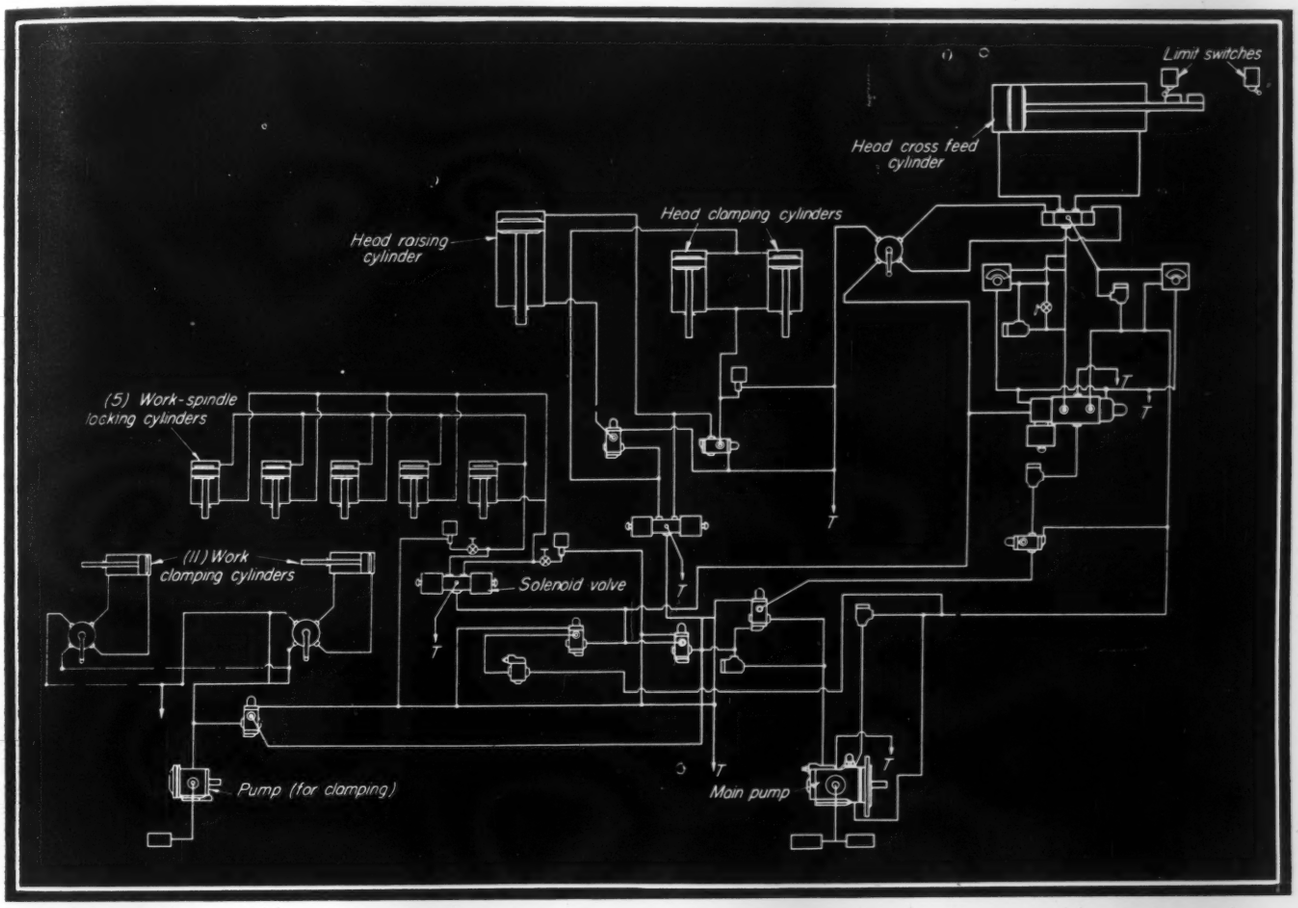
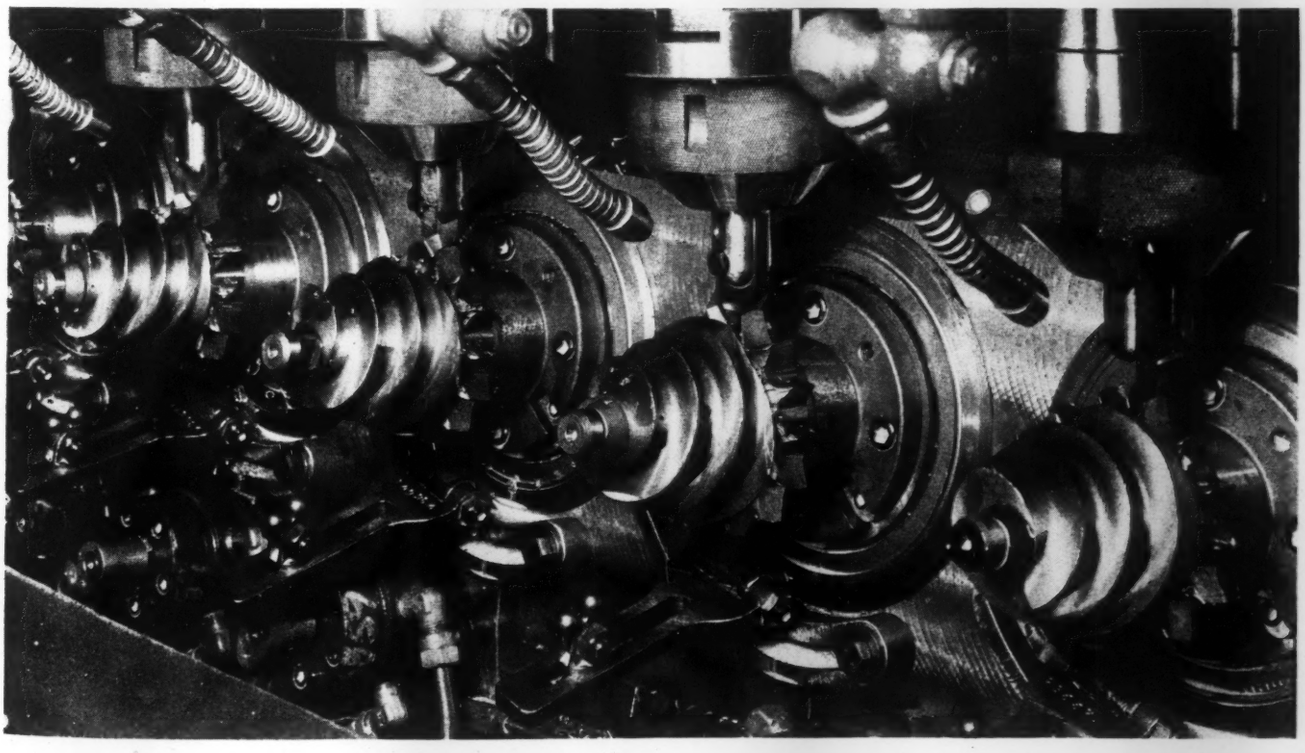


Fig. 4—Above—Hydraulic circuit diagram showing head cross feed, head raising and clamping, work spindle locking, and work clamping cylinders and their control. Auxiliary pump is utilized for clamping functions

Fig. 5—Below—Close-up view of work spindles and cutter spindles. Hinged fixtures below work spindles are employed in setting up so that the position of the helix on each workpiece corresponds to that of the master



on the piston rod. These clamping cylinders are controlled manually by valves located beneath each spindle, as indicated in *Fig.* 5.

Design of the antibacklash worm gear drive used for indexing each work spindle is shown in *Fig.* 6. The gear is made in two pieces and is adjustable radially by the action of six tapered pins in circumferentially offset holes. One of these pins is shown at the bottom of the gear. The pin shown at the top is used only to maintain position of the two gear halves during their machining.

Hydraulic cylinder and linkage for locking the spindles is shown in *Fig.* 6. This cylinder actuates a brake shoe by a linkage with a 2:1 advantage, each shoe being sufficiently wide to lock the brake disks of two adjacent spindles. The disks are keyed to the spindles and the braking effort is exerted between the shoe and the spindle housing. *Fig.* 4 also shows these locking cylinders.

Because various styles of workpieces have different cone angles, the work-spindle arbor is designed so that it may be tilted at any angle up to 30 degrees. In this way the top of the workpiece can be set in the line of action of the cutter spindles. The right end trunnion for this arbor may be seen near the control stations in *Fig.* 1. Adjustment for tilting is one of the few manual adjustments and is effected by the worm and gear arrangement shown in *Fig.* 3 to the left of the work-spindle stations.

When it is desired to skew the teeth on the workpiece, a block and pin arrangement may be adjusted on the work-head ways in much the same manner as is employed on a lathe. This motion imparts an angular travel to the cutters, thus skewing the teeth on the bits.

Auxiliary Pump Supplies Clamping Power

In the hydraulic circuit, *Fig.* 4, is shown two separately driven pumps. Although the entire hydraulic system operates on 800 psi, an auxiliary pump is utilized for the clamping operations so as not to disturb any feed setups or head clamping. This pump also acts as an unloader for the main pump when the machine is running idle.

Lubrication of the work spindle gearing is oil bath, supplied by a separately driven pump. Lubrication to all other bearings and parts is by a centralized, piston-type system. In the operation and adjustment of this machine seven motors, 20 hydraulic cylinders and 14 brakes are utilized. The machine is working out exceptionally well in the customer's plant and its effectiveness can be judged by the fact that one operator is able to turn out approximately nine times as much production as he could on the equipment it replaced.

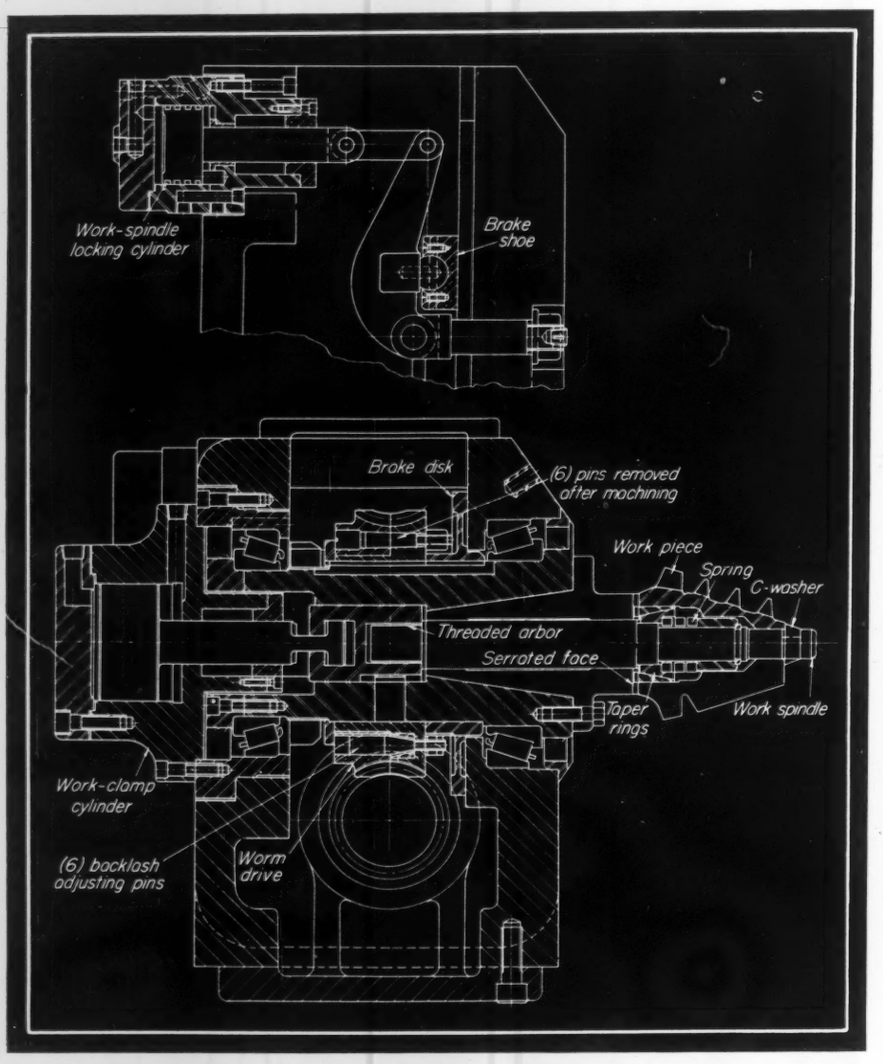
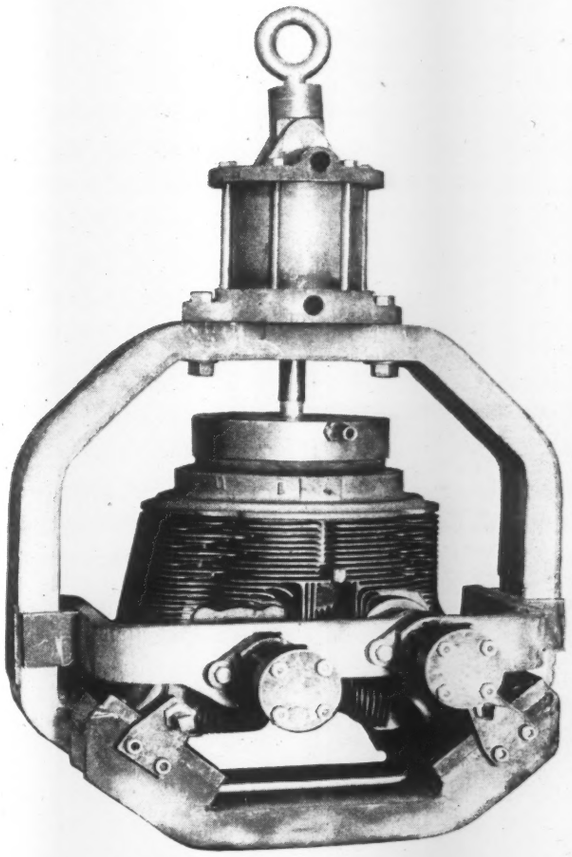


Fig. 6—Cross section of work spindle showing antibacklash worm gear and work-clamping and spindle-clamping features



Pneumatic Power and Control—Where They Fit

By Robert E. Becker
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Logansport Machine Co. Inc.
Logansport, Ind.

IN THE design of new machines or the conversion of existing equipment, the question as to what type of motive means and control should be used is of utmost importance. This one detail may determine the success of a machine or its failure as a better means to produce an article.

Choice of power means and control usually must be made from four types of commonly available sources, namely, air, hydraulic, electrical and mechanical. Of these four, three are available in practically all cases, in any plant. These are: Compressed air, electrical and mechanical. Hydraulic power usually must be installed, either as an accumulator system for an entire plant or by individual pump-

ing units for each machine or a small group of machines.

Many other factors enter into this problem of choosing the most suitable type of machine power and control. Compressed air is suitable for application to machines having clamping fixtures, work feeding devices, work ejecting mechanisms, shifting of control levers or tripping of valve controls for automatic sequence, driving machine spindles (by air motor), providing air cushions (such as a die cushion on a drawing press), moving of machine elements (such as retracting and positioning work), closing or opening safety doors, etc., or to actuate sealing plungers, as in the aircraft-cylinder water test fixture shown in the head illustration.

Although all of the above applications can be handled with hydraulic power, there is the fact that compressed

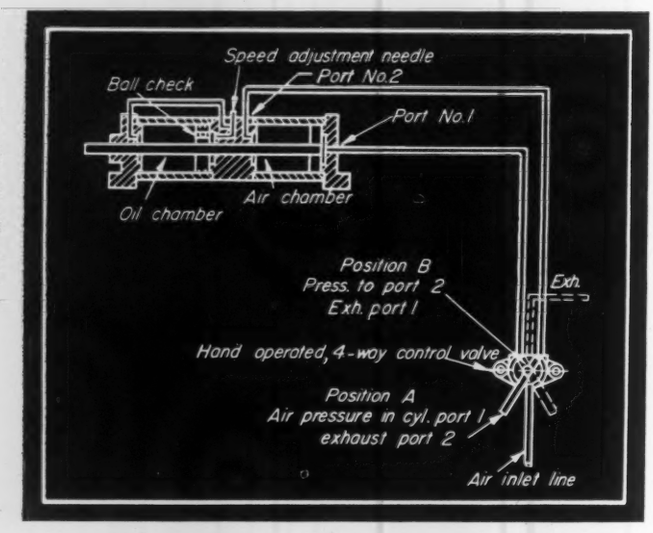


Fig. 1—Circuit employing combination air-hydraulic cylinder. Air pressure drives hydraulic piston against metered oil flow, thus maintaining constant the speed of the piston. Needle valve permits adjustment of speed

air, in practically all instances, is available and would not necessitate the installation of additional power generating equipment. Also the cost of hydraulic equipment is much more than air equipment due partially to the necessity of more precision in its manufacture and also due to the use of better grades of materials.

Of course the ultimate in good machine design is to utilize as simple a construction as possible. Thus, application of power to move various elements of a machine often calls for straight-line motion. Where such is the case, air or hydraulic cylinders for moving clamps, work, or tools, would be chosen instead of gear racks and pinions, toggles, cams and other intricate mechanisms.

However, the application of air is not suitable for all types of production machines where a power cylinder and control valves are desirable. Air cylinders are restricted in most cases to machines with low power requirements. The average air pressure available in most plants being 80 psi, it can be seen that in some cases it would be necessary to use a larger bore air cylinder to obtain sufficient power than could be mounted on the machine.

Other factors to be considered are the results obtained by the use of compressed air. Should it be necessary to provide a precision feed stroke to advance tools to work or vice-versa, air will not suffice. This is due to the compressibility of the medium which will result in an erratic motion of the cylinder. Controlled speed can be and is used on machines equipped with air cylinders, however, to perform other functions where an erratic motion of a few thousandths of an inch is not detrimental.

To obtain speed control that will be accurate, adjustable and metered, the use of hydraulic power is to be recommended. The fluid medium can be regulated, as to volume and velocity, which will result in the desired cylinder movement.

Combining an air cylinder and a hydraulic cylinder, *Fig.* 1, provides a means whereby compressed air can be used to move a tool carriage at constant speed by metering the oil, which is sealed in the hydraulic cylinder, from one side of the hydraulic piston to the other through an adjustable orifice. As will be seen in the illustration, the cylinder is made with separate air and hydraulic pistons assembled as an integral unit on a common piston rod. Rod movements are powered by the air cylinder, which may be controlled by any type of air valve. The two chambers in the hydraulic cylinder are connected externally in a self-contained circuit and an adjustable speed-con-

TABLE I

Approximate Air Consumption

Diam. of Cyl. Bore (inches)	Travel of Piston* (inches)	Amount of Free Air Consumed in Each 1 inch Travel of Piston when Compressed to 80 lbs* (cu ft)	Amount of Compressed Air Consumed in Each 1 inch Travel of Piston† (cu ft)
1½	1	0.0065	0.0010
2	1	0.012	0.0019
2½	1	0.018	0.0029
3	1	0.026	0.0040
4½	1	0.059	0.0091
6	1	0.103	0.0160
8	1	0.185	0.0287
10	1	0.293	0.0455
12	1	0.420	0.0651
14	1	0.575	0.0897
16	1	0.662	0.1028
18	1	0.948	0.1472
20	1	1.071	0.1663

* By free air is meant normal atmospheric conditions of the air at the point where compressor is installed. This table is based on sea level conditions. These figures principally are of use only in determining the size of compressor required to deliver a required volume of air.

† Amount of compressed air consumed in cubic feet is the same at all pressures. The piston travel in a double-acting cylinder is twice the stroke. For compressed air consumption, when piston travel exceeds one inch, multiply the cubic feet consumed in one inch travel by total number of inches piston is to travel.

trol valve in this circuit regulates the flow of oil, hence the speed of rod movements.

Obviously, speed must be attained in high production machines. For such equipment compressed air is the logical power medium because the velocity of compressed air is many times greater than that practicable with fluid power through pipes and valves of equal size. As the velocity of compressed air at 80 psi admitted to a cylinder is approximately 600 feet per second, providing the full capacity of the pipes and valves is being utilized, it readily can be seen that an air cylinder of the proper bore to provide the necessary power to move the imposed load will move very rapidly when compared to a fluid-driven cylinder, inasmuch as 30 feet per second is high velocity through hydraulic control valves and pipes. However, this high speed may not always be desired, except to load

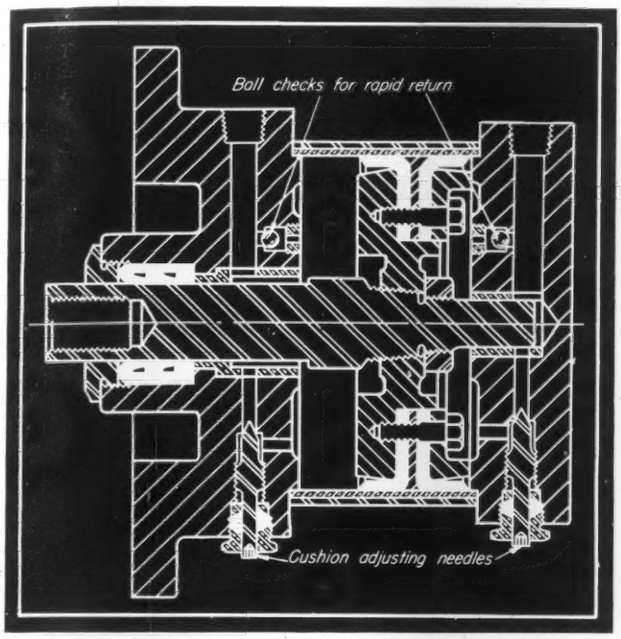


Fig. 2—Cushioned air cylinder in which speed of piston can be adjusted. For movement in either direction, the exhaust air, being blocked by the ball check, must pass through needle valve orifice which is adjustable

or unload work, operate clamps or effect other functions that sudden acceleration and stopping will not affect adversely. This one detrimental feature of high speed, i.e., sudden starts and stops, can be reduced somewhat—and in most cases to such an extent that many machine functions can be speeded up—by the addition of cushion features built into the air cylinder, *Fig.* 2.

Other factors to consider are heat and cold. The location of the machine usually determines this condition although in certain industries—for instance the glass industry—air-operated machines handle material of very high temperature. Often the cylinder and control valves are required to operate in temperatures of 300 to 400 F. This necessitates the use of low-expansion materials in the valves and cylinders, fabricated to compensate for the resulting expansion to provide as tight a control unit as possible. Were hydraulic power employed in such applications, it would be necessary to install an extensive cooling system. Also the deterioration of the fluid medium would be greatly accelerated, necessitating frequent shut-downs to drain the system and refill with fluid.

Ordinarily, applications for high temperature can be made with air equipment by simply providing the correct packings to withstand temperatures up to 200 F without altering the materials used in the standard product.

For installations operating in extreme cold, air controls are much more readily altered to meet the conditions. In the case of hydraulics, it would be necessary to install heaters in the fluid system to provide fluid at the proper operating temperature to secure satisfactory results from the control valves and cylinders.

Of course to attain the utmost from any machine, automatic operation is required. This can be accomplished by using pilot valves to operate the main control valves, the pilot valves being actuated by the moving members of the machine. Such an application is illustrated in *Figs.* 3 and 4. In this case when shutoff valve *G* is opened, air enters the four-way master control valve *C* through port *H*. Bleeder valve *A* has been depressed by trip arm *F* and thus bleeds off the left-hand end *J* of master control valve *C*. Air pressure which entered valve *C* through port *H* then leaves via port *K*, flows freely through speed-control valve *D* to enter cylinder *E* through port *L*, causing the piston rod to move up. When trip arm *F* strikes bleeder valve *B*, pressure is removed from the right-hand end *N* of control valve *C*, permitting pressure to pass from valve *C* via port *M* to enter cylinder *E* through port *Q*, causing the piston rod to move down. Exhaust air ahead of the piston leaves the cylinder via port *L* to enter speed-control valve *D*. The flow of exhaust air on the down stroke of the piston rod, being regulated by the needle in valve *D*, governs the speed at which the rod moves down. Reciprocation of the piston will continue until the air pressure to the main valve is shut off. Control also can be achieved by using electrically operated main control valves and limit switches which would be contacted by moving members of the machine.

This method of control is shown in the circuit diagram

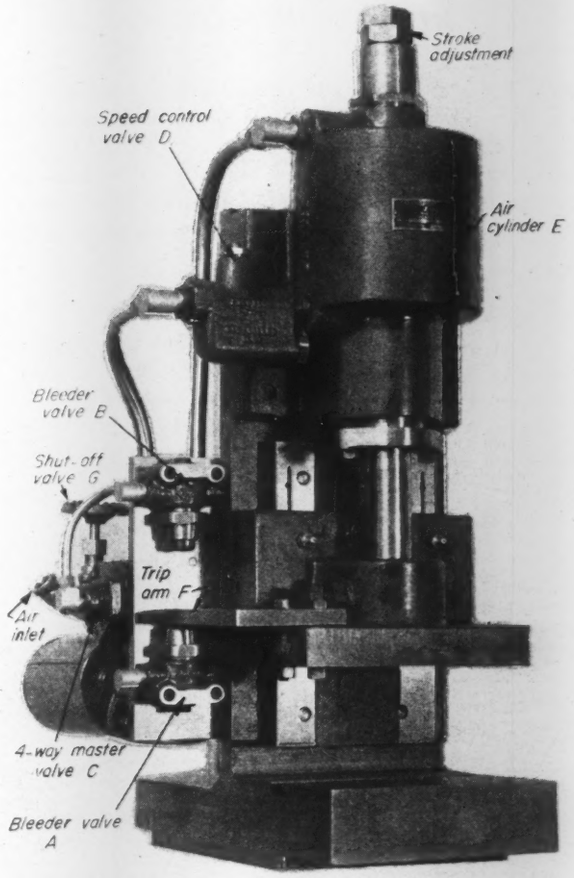


Fig. 3—In this air-powered press, automatic operation is effected through actuation of the bleeder valves by the trip arm F at each end of the ram stroke. Circuit diagram of this installation is shown in Fig. 4

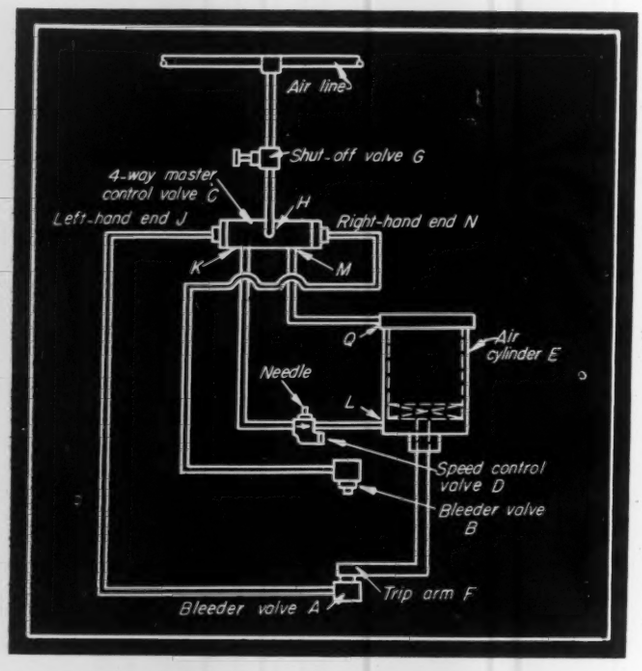


Fig. 4—Circuit diagram of the pneumatic power and control system used on the press shown in Fig. 3. Continuous automatic reciprocation of the piston will continue until the shut-off valve G is closed

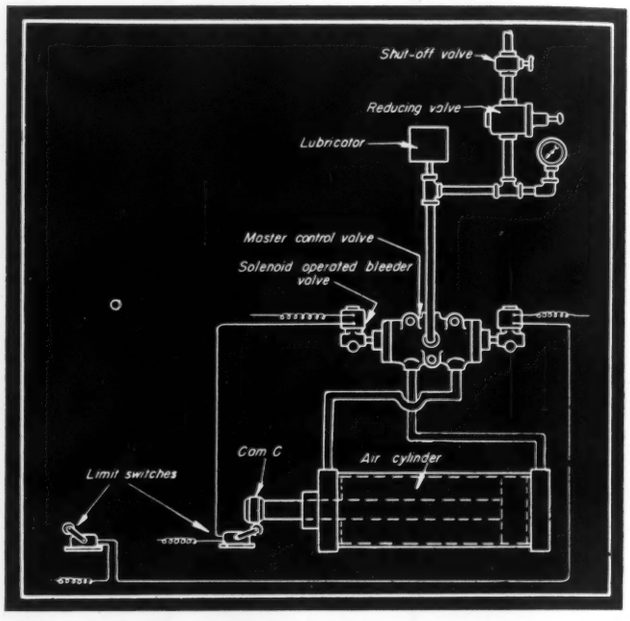


Fig. 5—Continuous operation is achieved in this circuit by actuating limit switches at each end of stroke

of *Fig.* 5 wherein the main control valve is solenoid operated through limit switches which are contacted at the end of each stroke, forward or reverse, of the air cylinder. In some cases the loading and unloading of work pieces may require a lapse of time between cycles that would be of too long a duration to control automatically. In this case a combination control might be used, wherein the operator starts the cycle after loading the work and the machine then takes over and automatically functions through one cycle, stopping for unloading of the work.

A control of this type is illustrated by the circuit diagram of *Fig.* 6. After loading work into the machine the operator depresses bleeder valve *A*, thus applying air pressure to bleeder valve *B*, (which along with the main valve is located as close to the air cylinder as is possible), thus opening bleeder valve *B* and causing the main-valve spool to shift, admitting air pressure to the closed end of the air cylinder, which now moves forward to the end of its stroke. At this time a cam or trip dog attached to a moving member of the machine contacts and operates bleeder valve *C* which causes the main valve spool to shift to the opposite position. Air then is directed to the rod end of the air cylinder, causing it to move "in" or to its start position where it stops for the operator to unload the finished work.

Sequence timers can in some cases be used to great advantage. This would be the case when air or hydraulic power is applied to plastic presses, pulp molding presses, etc., where it is necessary to control accurately

TABLE II

Comparative Cost of Compressed Air (Gage Pressure: 80 psi)

Amount of Free Air In Cubic Feet Consumed Per Minute	Power Required For Compressing Free Air To Gage Pressure of 80 Pounds Per Sq. Inch		Power Required For Compressor Motor Assuming 80% Efficiency	Cost Per Hour (in cents) For Compressing Free Air From Atmospheric Pressure To Gage Pressure of 80 Pounds Per Square Inch				
				Rate Per Kilowatt-Hour In Cents				
	Horse Power	Watts	Actual Watts Required	10 Cents	8 Cents	6 Cents	4 Cents	3 Cents
1	.158	118	147.5	1.48	1.18	.89	.59	.45
10	1.58	1180	1475	14.8	11.8	8.9	5.9	4.5
12	1.895	1416	1770	17.7	14.2	10.6	7.1	5.3
14	2.21	1650	2060	20.6	16.5	12.4	8.3	6.2
16	2.52	1887	2360	23.6	18.9	14.2	9.5	7.1
18	2.84	2121	2650	26.5	21.2	15.9	10.6	8.0
20	3.16	2360	2950	29.5	23.6	17.7	11.8	8.9
22	3.48	2596	3240	32.4	25.9	19.4	13.0	9.7
24	3.79	2832	3540	35.4	28.3	21.2	14.2	10.6
26	4.11	3065	3830	38.3	30.6	23.0	15.3	11.5
28	4.43	3300	4125	41.3	33.0	24.8	16.5	12.4
30	4.74	3540	4425	44.3	35.4	26.6	17.7	13.3
32	5.04	3775	4720	47.2	37.8	28.3	18.9	14.2
34	5.37	4000	5000	50.0	40.0	30.0	20.0	15.0
36	5.68	4242	5300	53.	42.4	31.8	21.2	15.9

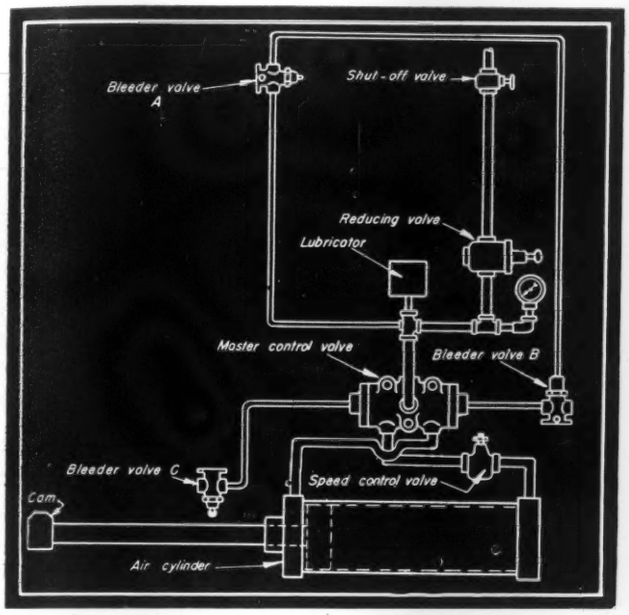


Fig. 6—Depressing bleeder valve A in this system results in operation through one complete cycle only

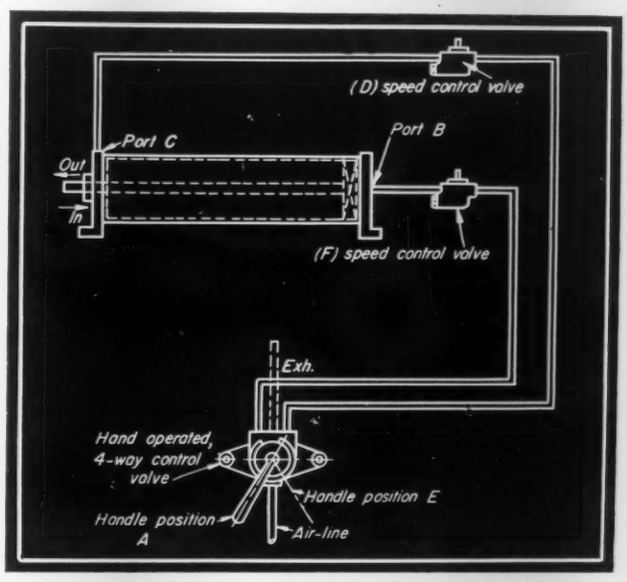


Fig. 7—How reduced speeds can be achieved by using speed-control valves in exhaust lines rather than by reducing the size of the main control valve

the duration of any one position of the power cylinders.

The wide variety of air and hydraulic control valves available permits the designer to choose many combinations. For example, some types of control are: By cam, by air or hydraulic pilot pressure, by solenoid, or any combination of these. However, as has been indicated, the choice of air wherever possible permits the use of less expensive equipment for machines not requiring high operating pressures to obtain the cylinder power required.

Cylinders, either air or hydraulic, are available in many standard mountings including foot, centerline, rod-end flange, base-end flange, clevis and any special mountings that may be required to fit a specific space. In regard to valve sizes, pipe sizes, etc., the designer is not, except in rare cases, confronted with the necessity of computing the flow of air through pipes and valves. This is due to the fact that manufacturers of this type of equipment have designed air cylinders and valves to provide the maximum operating efficiency and, upon determining the bore of the cylinder required, a control valve of the same size as the pipe inlet in the cylinder can be selected.

However, should it be necessary to compute the theoretical flow of compressed air through pipes, bends, elbows and tees to determine the approximate expected or required cylinder speed, it can be done in the following manner: First, to determine the theoretical flow through clean, smooth, straight pipe, employ the formula

$$V = 58\sqrt{\frac{pd^5}{WL}}$$

wherein V = Volume of air in cubic feet per minute

p = Difference in pressure at the two ends of the pipe in pounds per square inch

d = Inside diameter of pipe in inches

W = Weight in pounds of one cu ft of entering air

L = Length of pipe in feet.

Next, to compensate for fittings and bends, the following table gives the length of straight pipe equivalent to elbows and tees:

Diameter of pipe	¾	1	1½	2	3	4	5	6
Additional length of pipe (ft)	.8	1.3	2.7	4.7	8.7	13.3	18.6	24

Pipe bend effects vary with the character of the bend,

TABLE III

Comparative Cost of Compressed Air

Gage Pressure In Pounds Per Square Inch	Power Required For Compressing 1 Cubic Foot of Free Air Per Minute From Atmospheric Pressure To Gage Pressure		Power Req'd. For Compressor Motor, Assuming 80% Efficiency	Cost Per Hour (in cents) for Compressing 1 Cubic Foot of Free Air From Atmospheric Pressure To Gage Pressure				
				Rate Per Kilowatt-Hour In Cents				
	Horse Power	Watts	Actual Watts Required	10 Cents	8 Cents	6 Cents	4 Cents	3 Cents
60	.136	101.5	126.9	1.27	1.02	.76	.51	.38
65	.141	105.01	131.3	1.31	1.05	.79	.52	.395
70	.147	109.8	137.1	1.37	1.1	.82	.55	.41
75	.152	113.3	141.6	1.42	1.14	.85	.57	.425
80	.158	118.0	147.5	1.48	1.18	.89	.59	.45
85	.162	121.0	151.1	1.51	1.21	.91	.60	.46
90	.167	124.6	155.8	1.56	1.25	.93	.63	.465
95	.171	127.5	159.2	1.59	1.27	.95	.64	.475
100	.176	131.3	164.0	1.64	1.31	.98	.66	.490

with the least resistance being offered when the radius of the bend is equal to five times the radius of the pipe. To transpose the effect of a bend in the pipe to the equivalent length of straight pipe, use the formula

$$L = 12.85\, l \left(\frac{r}{R} \right)^{0.83}$$

wherein L = Equivalent length of straight pipe in feet
R = Mean radius of bend in feet or inches
r = Inside radius of pipe in feet or inches
l = Length of bend in feet measured along the center line.

In the case of a bend which has a radius of five times the radius of the pipe the resistance of the bend is approximately equal to a straight length of pipe 3 1/3 times the length of the bend when measured along the center line.

Referring to TABLE I, the theoretical time in seconds required for an air cylinder piston to travel a specified distance can be determined by dividing the volume of air supplied to the cylinder as calculated from the above formula by the figure given opposite the cylinder bore in the fourth column and multiplying this quotient by 60.

To assure the maximum efficiency and proper operation of air equipment, main control valves should be selected to provide the correct volume of air necessary for maximum operating speed of the cylinders. Should it be necessary to operate one or more cylinders on a machine at reduced speeds, a speed control valve should be used to throttle the exhaust air from a cylinder, *Fig.* 7, rather than attempt to obtain satisfactory results by reducing the size of the main control valve. Referring to the circuit diagram of *Fig.* 7, with the hand-operated, four-way control-valve handle in position A, air flows freely through port B of the cylinder. Exhaust air leaves the cylinder via port C and its flow is controlled by speed-control valve D, hence controlling the speed at which the piston rod moves out. With the valve handle in position E, air flows freely through port C of the cylinder. Exhaust air leaves the cylinder via port B and its flow is controlled by speed-control valve F, hence controlling the speed at which the piston rod moves in. When it is necessary or advantageous to operate more than one cylinder from one main control valve it is necessary that a valve be selected that will be of sufficient size to provide a flow equal to the combined volume requirements of the cylinders to be operated.

Thus far, costs have not been considered in the above discussion. As stated, the assumption that compressed air is available in practically all industrial plants was made. But where this is not the case or where the present compressor units are loaded to capacity, it becomes necessary to determine the air consumption of the added equipment. From this data a comparative cost of compressed air and hydraulic power must be computed before a decision can be made as to whether the machine should be air or hydraulic powered.

The following example is given to illustrate the comparison of horsepower required to generate a given amount of power by pneumatic and hydraulic pressure:

Assuming a machine to require 9000 pounds pressure from the power cylinder, 12-inch stroke and 300 operations per hour, air to be supplied by a 3-stage compressor at 90 psi, or hydraulic power at 500 psi from a suitable pump. Then in the case of the pneumatic equipment

9000/90 = 100 sq. in., area of piston
100 x 12 = 1200 cu. in. per stroke
1200 x 300 = 360,000 cu. in. compressed air per hr.

Compression ratio at 90 psi is 7.1. Thus
360,000 x 7.1 = 2,556,000 cu. in. free air per hr.
2,556,000/1728 = approx. 1500 cu. ft. free air per hr.
= 25 cu. ft. free air per min.

It requires 14 hp to compress 100 cubic feet of free air per min. to 90 psi. The total power required then equals 25 x 14/100 which equals 3.5 hp.

For hydraulic:
9000/500 = 18 sq. in., area of piston
18 x 12 = 216 cu. in. per stroke
216 x 300 = 64,800 cu. in. per hr. at 500 psi
64,800/231 = 280 gallons of fluid to be pumped per hr.
or 280/60 = 4.7 gallons per minute

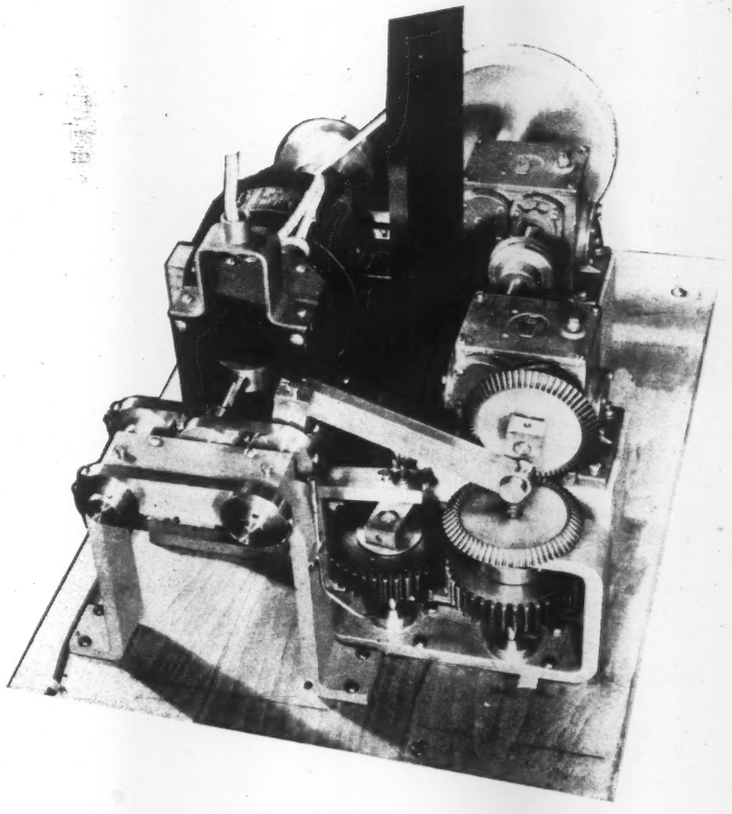
Then from the characteristic curve pertaining to the pump under consideration the horsepower required to pump one gallon at the above pressure can be found, which when multiplied by the number of gallons to be pumped per minute will result in the number of horsepower required. In this case a pump was used which required .44 hp per gallon pumped at 500 psi pressure. Then 4.7 gpm x .44 hp per gallon = 2.07 hp. Thus in this case, 3.5 hp is required for operation by compressed air and 2.07 hp by hydraulic.

From this computation it is found that the horsepower required to compress the air is approximately 60 per cent greater than for pumping the hydraulic power. Also the initial price of the compressor unit and the necessary auxiliary equipment will be much greater than the cost of the hydraulic unit which could be provided to operate the machine. Operation and maintenance also will be greater for the compressor unit than for the hydraulic unit.

However, the compressor unit can be selected with a large safety margin, and although additional horsepower will have to be used for driving, the unit will provide sufficient additional compressed air to operate other machines that otherwise would necessitate the purchase of individual hydraulic units for each machine or a central hydraulic system which would exceed the compressor cost.

In TABLE I is given the approximate free air consumption of various bore cylinders which is necessary for the selection of the proper capacity compressor unit. Further comparative costs of compressed air may be obtained in TABLES II and III.

Although the foregoing discussion covers numerous points to be considered in selecting pneumatic power and controls there are many conditions that must be taken into consideration which are controlled by factors not directly connected with the problem of machine control, such as company policy regarding production machine design, the necessity of acquiring able operators, etc.



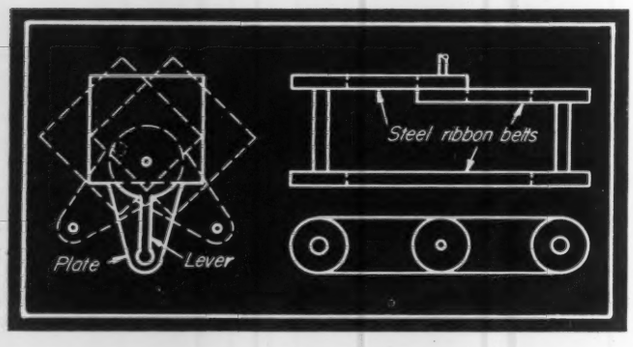
Engineers' Symposium

In this Engineers' Symposium, outstanding drive and control features of various types of machines are discussed with respect to specific problems, the solutions to which are embodied in the designs illustrated. It is hoped that the features and principles presented may suggest the answers to other drive or control problems

Simulates Wrist Motions

By L. A. Elmer
Apparatus Development Department
Bell Telephone Lab., New York

TO CARRY out tests on certain secret war apparatus, it was necessary to simulate mechanically the action of a person's hand and wrist in moving a lever along a horizontal arc and at the same time in rotating it around its own axis. These motions operate potentiometers, and neither in itself is difficult to simu-



late. At two positions of the axial rotation, however, a toggle switch is operated, and as the toggle snaps over to its new position, the lever must be able to follow it rapidly for a short distance so as not to interfere with the action of the switch. If the lever were operated by hand, this snapping action would be accommodated by the flexibility of the wrist. The complete motion required is thus a combination of two oscillations with a periodical quick flexibility twice each cycle of one of them. The apparatus developed for this purpose is shown in the accompanying photograph.

Rotates Housing About Lever Axis

To secure rotation in the horizontal plane, it was decided to hold the end of the operating lever fixed laterally and to turn the housing carrying the potentiometers and switch over an arc large enough to give the desired amount of motion. As shown at the left in the sketch, the end of the lever is held, and the housing is rotated—the two extreme positions being shown in dashed lines. With the end of the lever fixed, it is simple to provide the rotation of the lever around its own axis by fastening a drum to the lever and rotating it the desired amount. Oscillation of the housing is secured through a connecting rod linking a pin in the housing with a pin in a crank attached to a rotating gear, as shown in the photograph on the preceding page.

To rotate the operating lever around its own axis, and at the same time to hold it in one position so that the housing can be oscillated with respect to it, an arrangement of pulleys as indicated in the right-hand sketch was provided. Two pulleys at each end are on common shafts and move together. The central pulley, which is double the width of the others, is fastened to the operating lever which rotates with it. Belts are thin steel ribbon and, as each is fastened by screws to the two pulleys over which it passes, no slipping is possible. This pulley system is driven by a crank, shown in the photograph. Because of the positive drive from two sides, the pulley fastened to the operating lever is held in place laterally although free to move a small amount up or down to absorb slight wobble in the operating lever from the rotation of its housing.

Springs Supply Flexibility

To provide the flexibility needed when the toggle switch operates, this pulley has two rotating members: One fastened to the operating lever and the other driven by the steel belts. These two parts are connected by a set of springs in such a way that regardless of the direction of rotation the operating lever will be driven through springs. As the toggle switch operates, thus removing the back torque on the operating lever, the section of the pulley attached to the lever rapidly follows it because of the release of tension in the driving spring, and thus no restraint is offered to the toggle action.

The complete drive, shown in the photograph, consists of a small motor with a three-step pulley that drives another three-step pulley connected through two sets of reducing gears to a bevel gear. This gear carries the crank that oscillates the operating lever around its own axis, and also drives a second bevel gear on a vertical axis. On the same shaft as the second bevel gear is a spur gear that drives a similar spur gear at a ratio of 38 to 40. This latter gear carries the crank that oscillates the housing. Because of the 38 to 40 speed difference of the two drives, twenty oscillations of the control lever on its own axis are carried out while the housing is oscillated nineteen times, and thus in each twenty oscillations the two motions have been in every possible position relative to each other. Depending on which step of the driving pulley is used, the oscillations will occu at the rate of 0.5, 1 or 2 per minute.

Push-Pull Mechanism Simplifies Design

By John S. Baker
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Douglas Aircraft Co., Santa Monica, Calif.

DESIGN of pressure cabin airplanes has necessitated a more refined door and door operating mechanism than were employed previously. The need for outward opening passenger doors, as a safety feature for passenger operation, requires that the latches cannot be of the fixed type. Pressure loads to be supported and the necessity to control basic contours of the airplane under pressurized conditions require latches of considerable strength at close intervals. In addition, it is imperative that there be a central operation handle to simplify door operation.

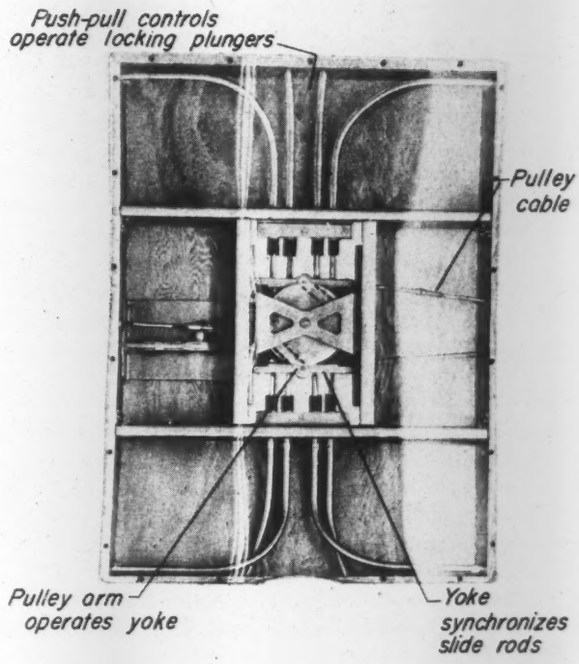
With these basic requirements in mind the advantages obtained through the use of push-pull controls of the Simmonds Accessory type are fairly apparent when the basic shape of the door is such that rigid push-pull tubes can-

not be used without an excessive number of bell cranks and their supporting brackets.

The design problem resolves itself into a matter of developing supporting latches to carry the structural loads and some central mechanism in the door to give the required motion to these latches, the latches being joined by push-pull controls that can be formed to the necessary shapes. The only other requirement is that the shapes required fall within the mechanical limits of the push-pull control. In a large door, by judiciously selecting latch points and by giving proper consideration to the minimum bend radii as well as to the required straight sections at each end of the control, the problem may be worked out satisfactorily.

It may be seen from the illustration that the only door tooling necessary, in addition to the normal structural tooling required to assemble the door, is for the location of the control mechanism and the latch support points.

Structural design of the door is simplified also to the extent that the structural material need not be placed to support the intermediate control points necessary to change the direction of conrol forces, but may be located at the most advantageous positions for structural efficiencies.



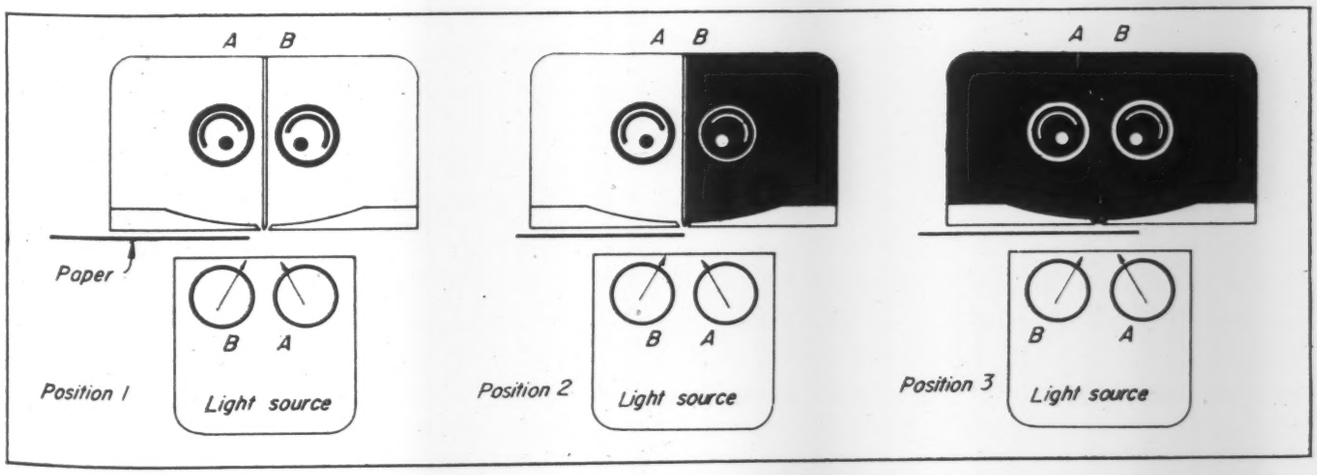
Phototubes Provide Edge Control

By Stephen J. Deitz
Process Engineer
United Cinephone Corp., Torrington, Conn.

MANY variations of the principle of utilizing photoelectric relays for indicating devices have been used in recent years for solving problems that have been otherwise impossible, difficult or costly to solve by other methods. The photoelectric relay is useful for such devices because it can be operated without expenditure of power from the source which operates it. Also, it creates no counter action to this source, is not subject to vibration and bounce and can be made to respond to an average movement though the operating means may contain irregularities along its edge or in its composition.

Photoelectric relays will respond to a stimulant which may be present for as short a time as a fraction of one-thousandth second. The important factor which limits the repetition rate at which they may be operated in industrial usage, however, is the operating time of the follow-up system to which they are connected. Operating from a vacuum-tube circuit, the electromagnetic relay, which opens and closes electrical contacts, will respond as many as 50 times per second.

An application that has found wide usage employs a photoelectric relay for solving the problem of maintaining



alignment of the edge of a surface with respect to another surface or object. In this case the surface edge is that of thin paper passing from a reel into a rotary press at high speed. Due to the fragility of the paper edge, the slight irregularities thereon and the high surface speed, mechanical means could not be used successfully. The photoelectric relay used to solve this problem is of the conventional type with a special phototube and light source assembly tailor made to fit this particular application. The sketch shows this assembly and how it is affected by the lateral movement of the paper edge with respect to a margin line.

Two phototubes mounted in a common housing, are separated by a shield which prevents the light falling on one phototube from reaching the second phototube and affecting its operation. The bottom of this housing has a slot measuring 1/16-inch by ½-inch. The lower edge of the light shield is tapered and shaped so as to fit into this slot. This tapered edge divides the slot into two equal sections, each measuring less than 1/32-inch across.

Mounted below the phototube housing is a second housing containing two automobile type headlight lamps. The position of the lamp filaments is such, with respect to the phototube cathodes, that an imaginary line projected between these points would pass diagonally through the slots in the phototube housing. The lower edge of the light shield represents the margin line to which the paper edge must maintain alignment.

The sketch on the previous page shows the paper in three different positions. Position 2 is normal with the paper interrupting the light beam from lamp *B* to phototube *B* while allowing light from lamp *A* to reach phototube *A*. Under these conditions the relay contacts to the compensation mechanism are opened and the paper runs through the machine in a normal manner.

If the paper moves to the left as indicated in Position 1, light passes from lamp *B* to phototube *B*. This causes the relay in *B* circuit to operate and energize the left-compensation mechanism. When compensation is completed the paper will have returned to normal position again as shown in Position 2.

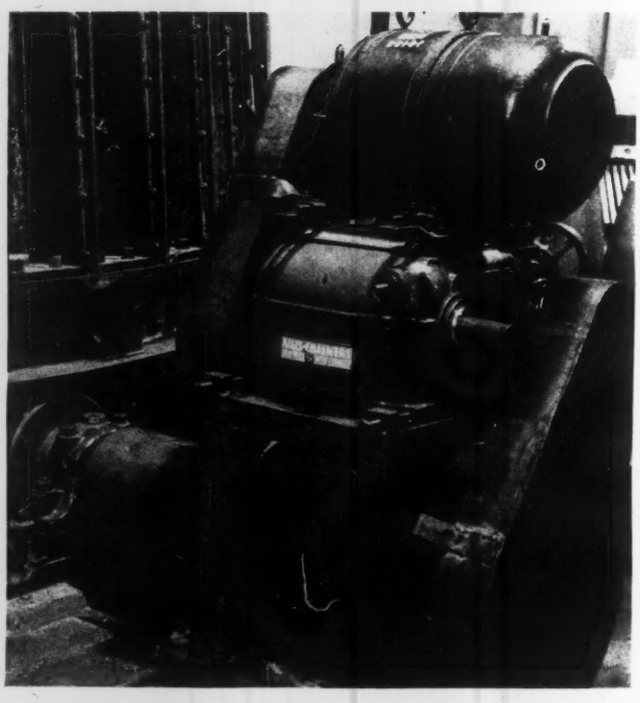
Position 3 shows the paper off to the right. Light beams from both lamps are interrupted and both phototubes are blacked out. The relay contacts in circuit *A* are closed and the right compensation mechanism is set in operation. When compensation is completed the paper will be in normal position again as in Position 2.

This arrangement will effect continuous correction when the paper position shifts laterally plus or minus 1/32-inch. The rate of speed of correction is manually controlled in the compensation mechanism according to the need for more or less compensation.

When the cross-sectional area of the beam is small, as in this case to permit precision operation, the intensity of the beam must be high to compensate for the reduction in active area of the sensitive phototube surface.

There are many and various problems in the field of machine design that can be solved by the use of photoelectric equipment. If an electrical switch can initiate control and the means by which the switch is to be operated cannot supply the necessary force, then another photoelectric relay application is in order.

Friction Drive Solves Problem



By Frank Rumble
Texrope Dept.
Allis-Chalmers Mfg. Co., Milwaukee

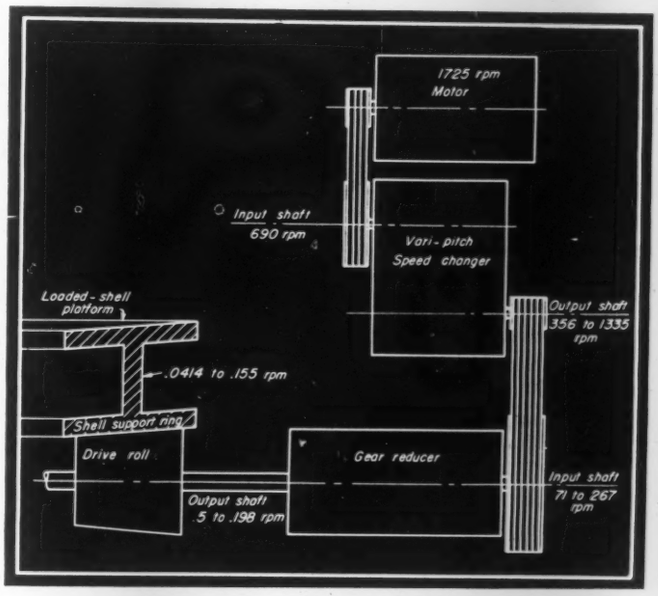
OBVIATING long chains or V-belts, the drive shown in the accompanying illustrations was designed for a machine to be used for x-ray inspection of artillery shells. When Ordnance officials planned to build the machine, a large iron ring or revolving mechanism, traveling slowly, was designed to carry the shells past a focal point where each shell would be photographed. In order to safeguard the workers from x-ray exposure, it was necessary to erect a concrete barrier across the ring between the workers and the x-ray equipment.

Continuous operation was desired so that shells could be photographed at a fast rate for detecting such flaws as inadequate wall thickness, casting defects or cavitations in the explosive charge, any of which might cause the shell to explode prematurely or miss fire.

Many details of the apparatus had been worked out, but the problem of driving the ring at a sufficiently slow and

smooth variable speed remained. A gear arrangement was abandoned as being too costly and unreliable. Use of chain or V-belts around the circumference of the ring was impractical because of the extreme belt length that would be required and because of the difficulty that would be encountered in case of a breakage in the belt or chain operating through openings in the concrete barrier.

The problem was solved by use of a friction drive and a variable-speed unit, as shown in the schematic diagram. The ring, mounted on four conical rollers, is driven through one of these rollers. Power is furnished by a 1725-rpm motor which drives a speed changer through a 2.5:1 ratio V-belt drive, producing a ratio of 3.75 to 1. The speed changer in turn powers a gear reducer rated 142:1 reduction through a 5:1 ratio V-belt drive. Total reduction at this point is .5 to 1.98 rpm. An additional reduction of 12.2:1 is secured by driving the ring through one of the conical roll supports. Final range of speed of the ring was from 0.0414 to 0.155 revolutions per minute.

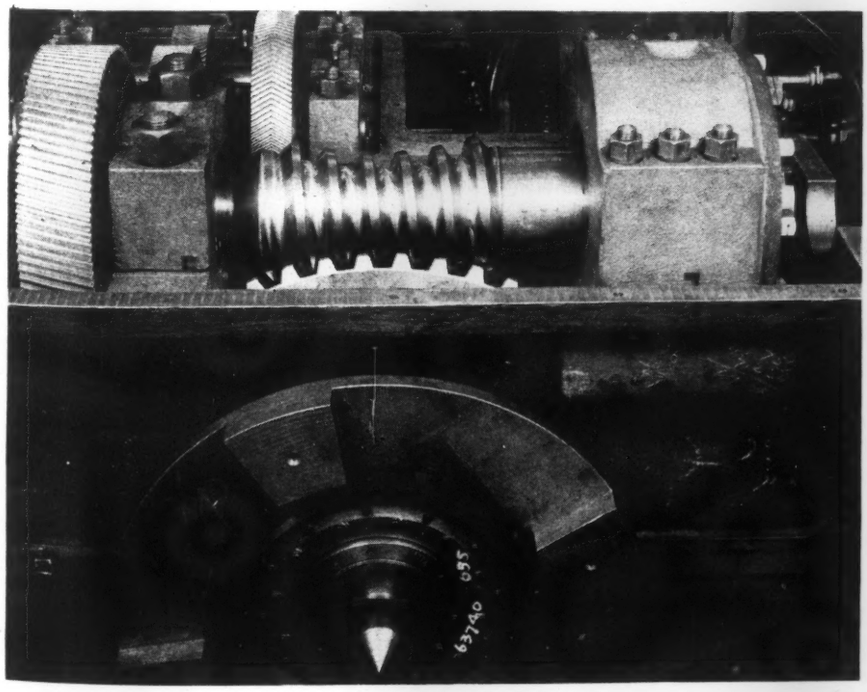


Compact Drive Obviates Chatter

By E. C. Denne
Gear Consultant
United Engineering & Foundry Co.
Pittsburgh

PREVIOUS designs of roll-lathe headstocks, including our own, incorporated a driving system of double-helical and spur gears, including two sets of speed change gears. The main pinion was overhung, driving an internal-tooth face-plate gear. The motor was usually mounted on top of the drive case, either toward or away from the face plate, resulting in a relatively large towering construction.

The new compact design, shown in the accompanying photograph, was made possible by the use of Cone-Drive gears for driving the face plate. These gears have the faculty of delivering high torques in a minimum amount of space and are noiseless and chatterless. Their use in this lathe was based on exhaustive tests, made over a period of two years, before actually incorporating them into our equipment. This design would not be feasible with conventional worm gears because the conditions of peak and speeds necessitate dimensions too great to be accommodated readily in desirable proportions.



The compact unit presents many distinct advantages, such as:

1. Low head room, permitting freedom of sight to the roll operator and craneman
2. Noninterference with crane movement
3. Uniform width—does not project beyond the clearance lines of the roll lathe proper, which might effect passageways

4. Noiseless and chatterless operation
5. Ability to furnish smooth and continuous power necessary to obtain fine roll finish
6. Drive case is dust free, totally enclosed and is about half the size of the old design, thus presenting no sound-board noises.

In the new design, the motor is mounted direct on one corner of the drive case and is coupled to the high-speed continuous type herringbone pinion with a gear type flexible coupling. The secondary gears are also of the continuous type herringbone-tooth design with a positive type coupling, or shifter, mounted between the two sets of gears for speed change purposes. The tertiary gear sets are of the single-helical type so as not to restrain the lateral adjustment of the Cone pinion. A thrust bearing of ample size is mounted on one end of the pinion shaft and is housed within a cartridge for adjusting purposes.

All bearings are of the antifriction type; some are restrained from lateral movement and others are free to float. The gears and bearings are provided with a copious supply of lubricant at all times, the lubricant being supplied by a motor-driven pump mounted near the main motor within the confines of the headstock case lines, or driven by chain from one of the gear shafts within the case proper, the drive method depending on the size of headstock. The Cone gear, besides being lubricated by spray, dips in oil at all times. The bottom of the drive case is used as the oil reservoir.

The range in speeds of the face plate varies from 0.58 to 8.7 rpm, depending upon the size of the lathe. The range is approximately 15:1, the motor supplying 4:1 and the change gears approximately 3.8:1 range.

Hydraulic Link Protects Press

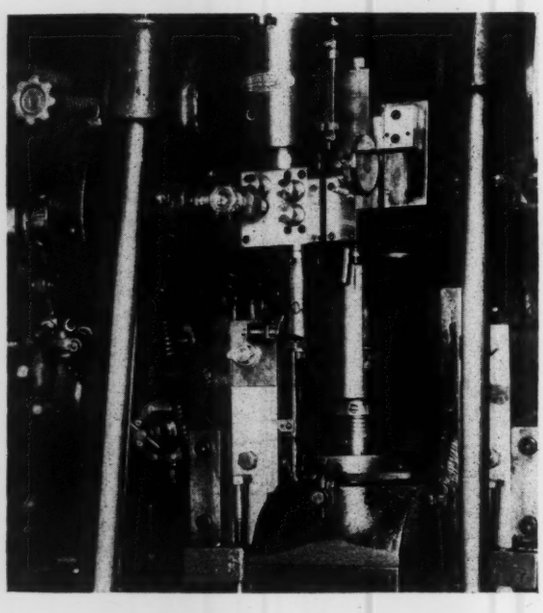
By D. A. Rogers

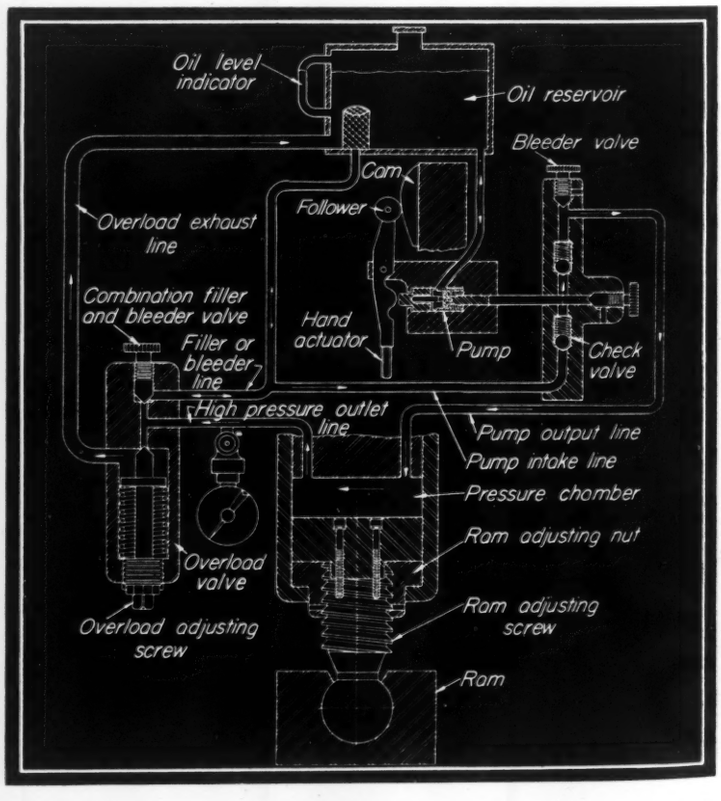
Dayton Rogers Mfg. Co., Minneapolis

To overcome overloading of punch presses in sizes from 30-ton up, a hydraulic overload connecting link shown in the accompanying illustrations has been developed to replace the connecting rod or strap now furnished with the average punch press. This hydraulic link prevents bending of the crank and throwing strains on the press frame. Also it is so designed that it can be arranged to protect against overload on the dies used in the press itself.

Pressure on the hydraulic cylinder is maintained automatically by a pumping mechanism which is actuated from a cam on the throw of the press. However, before the press is started this pressure is brought to the desired cushion pressure by a hand actuator.

During the work cycle of the press, should the ram become overloaded by any cause whatever, the piston retreats against the high-pressure chamber and the oil escapes through the overload valve into the reservoir. The pressure may be re-established manually by actuating the pump. After normal working pressure is restored in the high-pressure chamber, the press is ready for continuous work cycle.





The combination filler and bleeder valve is merely for removing the air in the oil line when assembling the hydraulic unit. Position of the working ram is always assured by the constant high pressure in the cylinder, maintained by the dribble pump and kept in regulation by the overload valve. Because the cylinder necessarily is small, the pumping mechanism is capable of maintaining high pressures up to 10,000 pounds per square inch.

Obtains Squeeze with Hydraulic Booster

By J. H. McCormick
Chief Engineer
Racine Tool & Machinery Co., Racine, Wis.

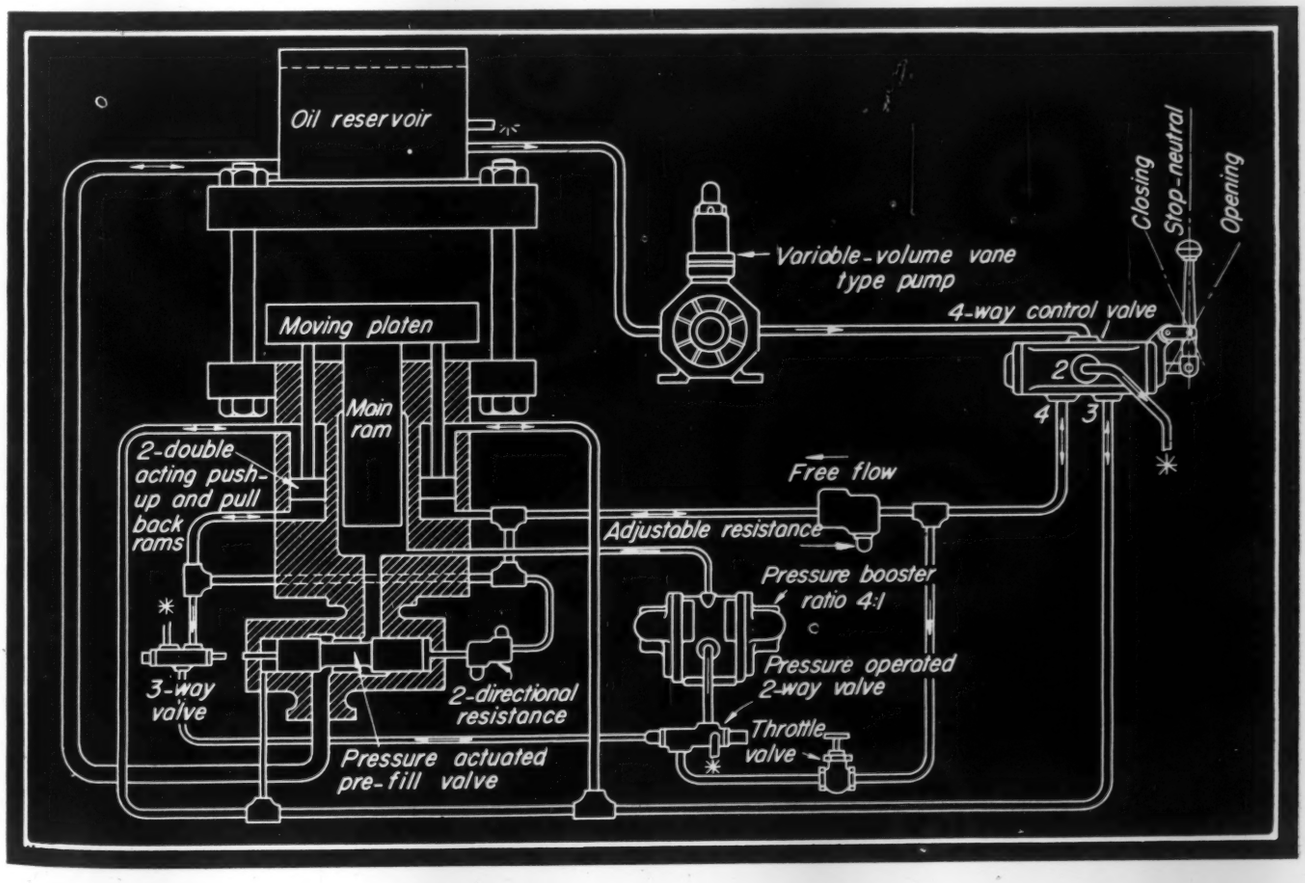
RAPID closing and opening of a molding press together with a high-pressure final squeeze is accomplished by the use of a small, variable-volume pump, prefill valve, and double acting pressure booster as shown in the circuit below. The same circuit and method of control could be applied to other machines having a similar cycle of operation.

This molding press employs a squeezing pressure of 400 tons which is developed by applying 3100 psi hydraulic pressure to an 18-inch diameter main ram and 775 psi to two 4½-inch diameter push-up and pull-back rams.

By using the equipment arranged as shown in circuit drawing, the press closes and opens under low pressure at a speed of 200 inches per minute. To pump directly into an 18-inch diameter cylinder and obtain a closing speed of 200 inches per minute, would require a large pump delivering 220 gallons per minute, driven by a correspondingly large electric motor. This rapid closing speed was developed, in this instance, by using a small 30-gallon per minute variable-volume pump driven by a 10-horsepower motor. Under operating conditions this motor usually has a load of less than 7½ horsepower.

Oil from this pump is applied to two small push-up cylinders which close the press. After the molds make contact, high pressure is automatically applied to the main ram through the use of an automatically reciprocated differential piston type pressure booster, having a pressure ratio of 4:1. The low pressure pump and control valves operate at 775 psi. However, with the aid of the booster, 3100 psi pressure is developed.

Opening and closing of the press is controlled by a



manually-operated four-way balanced-piston valve. This valve is constructed in such a way that when the lever is in the center or neutral position the press could be stopped in any part of its stroke while going either up or down. This arrangement permits short-stroking a press when it is not necessary to fully open the press in order to load the dies. This short-stroking is an economical arrangement for speeding up the complete molding cycle. Also the valve is designed so that, when it is set at neutral, pressure oil from the pump is ported direct to the reservoir. This permits the motor to be started under no-load condition. It also permits the motor to stand by under a no-load condition when the press is being loaded or unloaded.

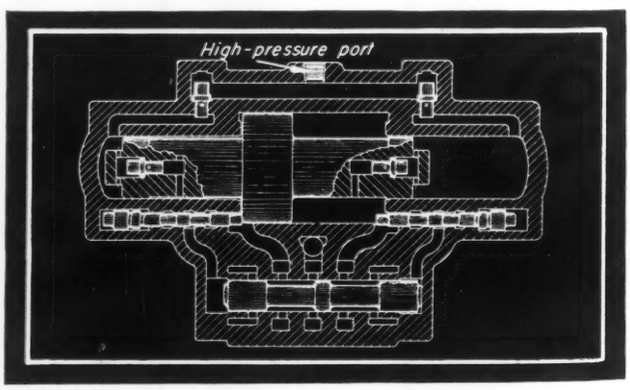
When the operator moves the lever of the control valve to the closing position, low pressure oil from the pump passes through the free flow and resistance valve to the head ends of the two push-up rams, lifting the moving platen. This action causes a suction to be formed in the cylinder of the main ram. The suction thus formed draws oil through the pressure-actuated prefill valve.

When the dies, attached to the moving platen, meet the dies attached to the top platen, pressure resistance builds up in the circuit leading to the push-up cylinders. The resulting increase in pressure opens the two directional resistance valves, applying pressure to the piston end of the prefill valve. This pressure causes the piston of the prefill valve to move, closing off the large pipe coming from the reservoir to the main ram cylinder. As soon as the piston of the prefill valve has moved to the closed position, a rod which is a part of the prefill valve, depresses the stem of the three-way pilot valve. This design of prefill valve is unique in that it assures that the prefill line is closed before high pressure is applied to the cylinder. In previous valves of this type, much high pressure oil has been lost due to high pressure being applied before the prefill valve was fully closed.

The three-way pilot valve is constructed so that its stem is spring offset to the "stem out" position. With the stem out, the pressure inlet port is blocked and the pilot cylinder port is connected to the exhaust. Thus the pressure actuated two-way valve is normally closed. When the stem of the three-way valve is depressed, it applies pressure to the pilot cylinder of the 2-way valve.

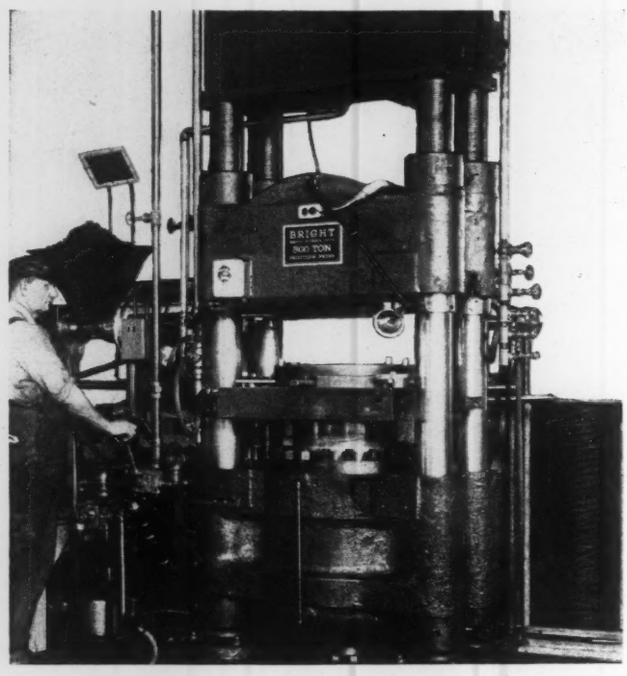
Application of pressure to the pressure-operated two-way valve opens this valve and applies low pressure from the variable-volume pump to the pressure booster. This unit converts low-pressure oil into proportionate higher-pressure oil. At the same time it proportionately decreases the quantity of low-pressure oil into smaller volumes of high-pressure oil. As shown in the sectional drawing, this pressure booster consists of a main ram of large diameter actuating two smaller rams. The main ram is automatically reciprocated so that its output is continuous as long as low-pressure oil is applied to the inlet. Since the booster is actuated by a low-pressure variable-volume pump, its high pressure output corresponds to the output of a variable-volume pump. Thus the compression stroke on the press can be maintained at high pressures without bypassing or relieving oil through a relief valve. The combination of the variable-volume low-pressure pump and the automatically applied pressure booster, results in an efficient circuit which consumes little horsepower and results in a smooth running, cool hydraulic system, since large volumes of oil and high pressure oil are not wasted through a relief valve.

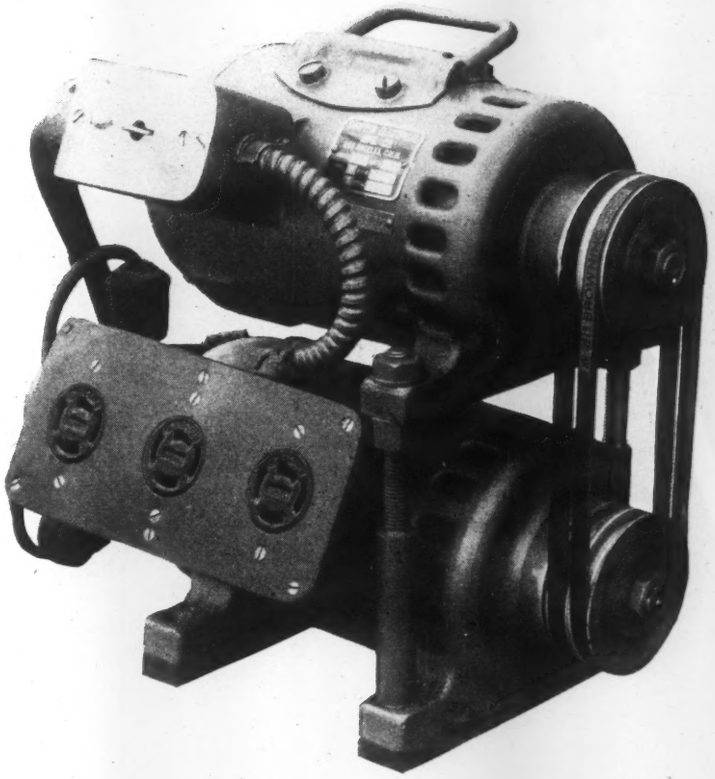
At the end of the molding cycle the operator moves the lever of the control valve to the opening position. This



action applies low pressure to the rod side of the two push-up and pull-back cylinders at the same time pressure is applied to the stem end of the pressure actuated prefill valve, thus opening the main ram cylinder connection to the reservoir. By using this method of returning the oil, the control valve can be small, since it is not necessary to pass the oil from the large ram through the control valve.

Use of the booster in this circuit has another advantage in that it can be attached direct to the press and the high-pressure line will be only one pipe of small diameter, not exceeding one foot in length. All other piping in the circuit is subject to low pressures only. Since the booster and the prefill valve are both designed with metal to metal ground joint seats, leakage of high pressure oil is reduced to a minimum.





Are High Speeds Required? Investigate High-Cycle Motors!

By Marion B. Sawyer
Vice President
Sawyer Electrical Mfg. Co.
Los Angeles, Calif.

DEMAND for increased production just prior to Pearl Harbor hastened development of high and varying frequency power drives and controls. The primary objective was to obtain, by direct motor drive, speeds far above conventional while maintaining the ideal characteristics of the induction type motor for speedier machining, drilling and shaping of nonferrous materials, plastics and wood. Likewise, where small diameter of cutters, drills, and grinding wheels required a higher speed than could be obtained by means of a standard 60-cycle motor, direct high-frequency drives would assure optimum machining conditions.

A short review of the outstanding qualities of the standard polyphase motor,

the common power drive of industry, will introduce and help clarify the subject of speed and control by means of varying and high frequencies. These outstanding qualities are as follows: (1) Constant torque under full load, (2) nearly constant speed under full load, (3) various set speeds according to the frequency and number of poles of the design (for instance, 60-cycle motors with 2-poles operate at 3600 rpm and with 4-poles operate at 1800 rpm, 120-cycle motors with 2-poles operate at 7200 rpm and with 4-poles operate at 3600 rpm, etc.), and (4) the absence of all moving electrical contacts, brushes and commutator.

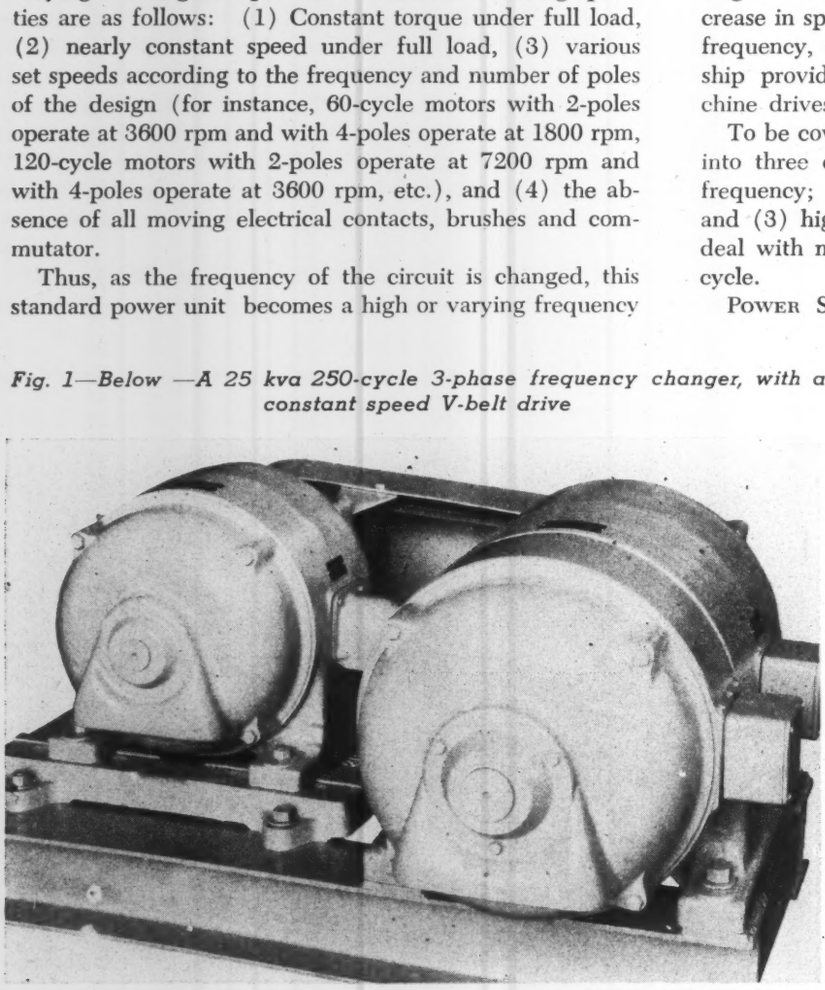
Thus, as the frequency of the circuit is changed, this standard power unit becomes a high or varying frequency drive and is limited in increased speed and horsepower only by its bearings and the structural strength of its rotating members. It can be seen from TABLE I, that the increase in speed, voltage, and horsepower is proportional to frequency, the torque remaining constant. This relationship provides ideal characteristics for many direct machine drives.

To be covered properly, the subject should be separated into three distinct topics: (1) Power sources for a set frequency; (2) power sources for a varying frequency; and (3) high-frequency motors. The first two items will deal with methods for producing current of nonstandard cycle.

POWER SOURCES FOR A SET FREQUENCY: As power sources the alternator (motor-generator set) and frequency changer are commonly used. The alternator is usually preferred in installations of over 50 kva output because of greater efficiency and better current characteristics. Current generated may be of any frequency desired depending upon the number of poles and the number of revolutions at which it is turned. If wound 8-pole and driven at 900 rpm, the output of the alternator would be 60-cycle, and if driven at 3600 rpm the output would be 240-cycle—frequency varying in direct proportion to the driven speeds. A higher frequency may be obtained by adding to the number of poles in the alternator or by increasing the speed of rotation, or both.

A frequency changer is the most common power supply source owing to simplicity of construction and low initial cost. The changer itself is merely an

Fig. 1—Below —A 25 kva 250-cycle 3-phase frequency changer, with a constant speed V-belt drive



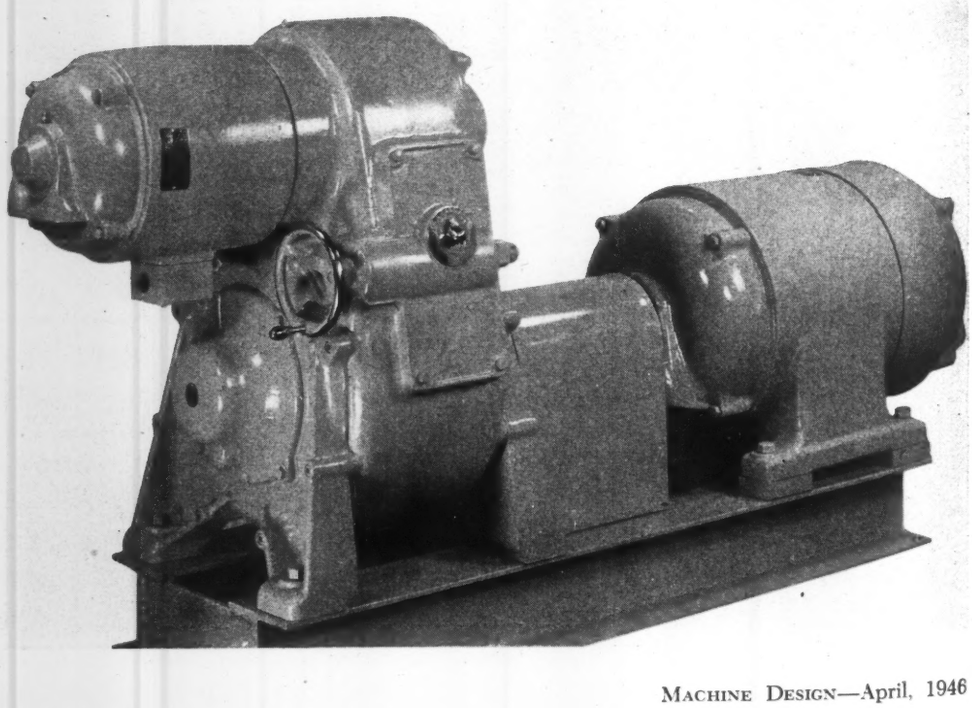


Fig. 2 — Right — Handwheel controls the drive ratio of this 20 kva changer providing variable-frequency output

induction motor with a wound rotor connected to slip rings for gathering output current, commonly known as a slip-ring motor, such as is used on elevator drives. Driven in a direction opposite to normal rotation, by separate belt or direct drive, such a motor becomes a frequency multiplier picking up the incoming line frequency and increasing it in proportion to the number of poles with which it is wound and multiplied by the number of revolutions at which it is driven, plus the input-line frequency. As an example, the output of an 8-pole frequency changer on a 60-cycle line, driven at 3600 rpm, would be 240-cycle plus 60-cycle, or a total of 300-cycle. A fixed 250-cycle, 3-phase frequency changer, V-belt driven, producing 25 kva at 305 volts is shown in *Fig.* 1. A portable type producing 2 kva is shown on the title page.

Where a number of high-cycle motors are to be driven from one power source, a fixed frequency is selected and all the motors used are operated at the same speed. Thus in portable grinding and polishing, 180-cycle is standard and produces 10,800 rpm. Again, on machines for the routing of aluminum 250-cycle is standard, producing 15,000 rpm. One kva of output is usually allowed for one horsepower of high-frequency drive and thus a battery of five 5-hp routers would require a 25 kva frequency changer. At first thought the kilovolt-ampere allowance per horsepower may appear to be low estimate. However, this rule is conservative since it is seldom found that all motors are running under full load at the same instant, and should this happen, the momentary overload capacity is ample to take care of the occasional demand.

TABLE I

High Frequency Characteristics of Standard Polyphase Motor
(5 Horsepower at 3600 rpm)

Frequency (c)	60	180	360
Horsepower	5	15	30
Voltage	220	660	1320
Speed (rpm)	3600	10,800	21,600
Torque (ft-lb)	7.3	7.3	7.3

POWER SOURCES FOR A VARYING FREQUENCY: Varying frequency is accomplished by changing the driven speed of a typical alternator or frequency changer so that the output frequency may be controlled in proportion to any speed between a minimum (the lowest speed at which it may be set) and the maximum (the highest safe speed to prevent mechanical failure). As previously noted, the rpm of the rotor determines the frequency produced. Variations are made without shutdown, all equipment continuing to operate under full speed and full load. This varying of the frequency requires some means for varying the speed of the alternator or frequency changer and is usually accomplished mechanically, although it may also be done electrically.

Illustrated in *Fig.* 2 is a 20 kva variable-frequency set in which the expanding and contracting of enclosed V-type pulleys, manually operated by a handwheel, varies the output cycles of the changer which is driven by a constant-speed motor. Often the handwheel is replaced with a fractional-horsepower motor so that a machine operator can control the frequency from some distant point or from the machine. An automatic index finger indicates the frequency or speed output.

A portable unit of 2 kva capacity, *Fig.* 3, is of the same general design except that all unnecessary weight has

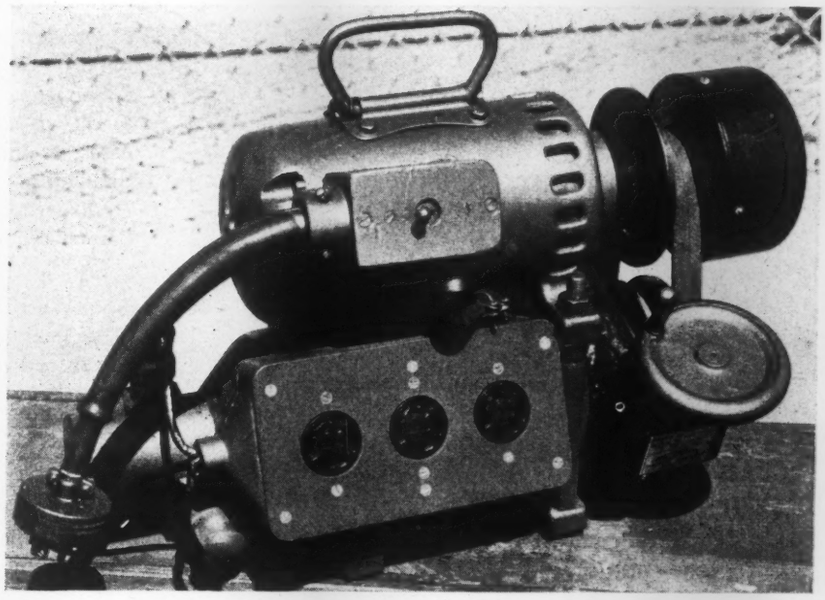


Fig. 3—Above—A portable variable-frequency-changer. Mechanical drives for such changers are limited to a maximum of 25 horsepower

Fig. 4—Below—Radial arm router using a 250-cycle 15,000 rpm motor for the routing of aluminum sheets

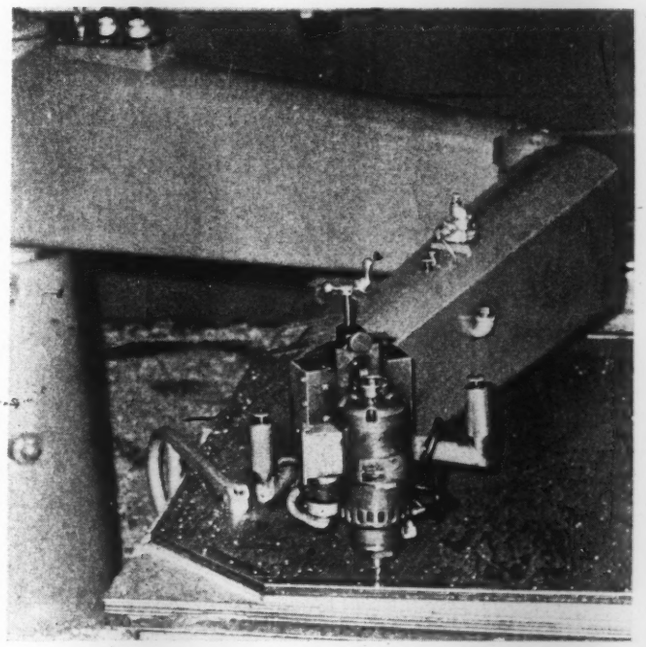


Fig. 5—Above—A high-frequency skull drill used in cranial surgery. Drill operates at 9000 rpm and a similar unit used for routing operates at 18,000

Fig. 6—Below—Radial drill for production of aircraft parts. Two sizes of drills are used with a separate air feed mechanism to each motor

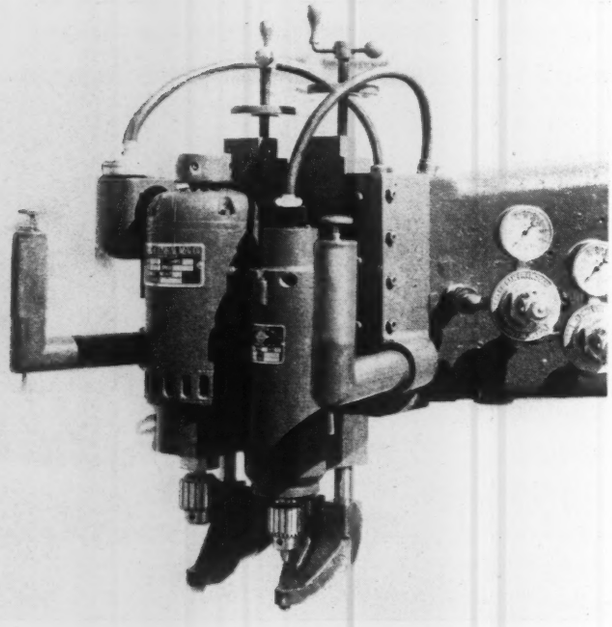
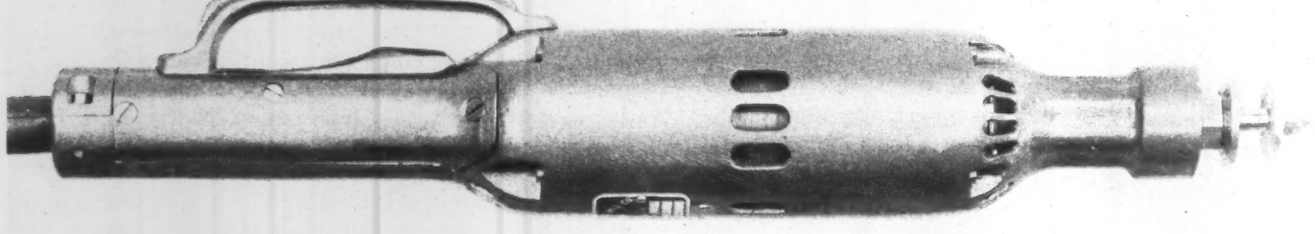


Fig. 7—Below—Direct drive eliminates excess weight and bulk. Rated at one horsepower this hand grinder, delivering 10,800 rpm, weighs but 8 pounds



been eliminated. V-belt and mechanism are open to show the method used for obtaining various speeds. Safe maximum power of a mechanical variable-speed drive is about 25 hp and, consequently, a frequency changer is limited to this capacity. However, this power is ample in most cases, as the frequency changer is always used as an individual power source for one motor to maintain the highest linear speed per minute on cutters and tools of various diameters.

Direct Current On Drives Over 25 HP

Where higher power output is desired at various speeds, as in the case of supplying power to model motors used in wind-tunnel testing, it is necessary to procure a direct-current power supply for a variable-speed direct-current motor which is required to drive the variable-frequency producer. This producer in turn is used to power an induction type motor thus eliminating the fire hazard present when commutator or slip-ring type motors are employed in wind-tunnel testing at high speeds. Cost eliminates the use of more than 25 hp in variable-frequency machine drives unless a direct-current source is readily available. There is a good possibility that electronics will solve the frequency-supply problem in the future, but up to the present time there is little or nothing of a practical nature available in tube sets for this purpose.

High-Frequency Motors: High frequency for direct drive, viz, instances in which the motor itself becomes the tool holder, has the great advantage of extremely high rpm constantly maintained so that small diameter cutters may have an ideal high linear speed at the cutting tip. A good example is the aluminum router on which aluminum sheets are stacked one-half to three-fourths of an inch deep and bolted to a table with a template pattern, *Fig.* 4. The motor is a 3-phase induction type, delivering 5 hp on 250-cycle current (15,000 rpm), and drives a 5/16-inch spiral cutter which will rout or cut at the rate of from 10 to 14 linear feet per minute. The motor is mounted on V-ways bolted to a double radial arm and will swing in a full circle so that the table setup may be prepared on one side while routing proceeds on the other. The motor has a hand-screw feed for full vertical travel and air feed between stops for cutter clearance to the depth of the cut.

Hand drilling and routing at high speed have an unusual adaption in cranial surgery. In *Fig.* 5 is shown a high-frequency skull drill with a 3-phase, ½-hp, 300-cycle motor wound 4-pole to produce 9000 rpm, while a similar unit used as a router to complete the operations drives a

small cutter at a 2-pole speed of 18,000 rpm. High-frequency current for this work is furnished by the small frequency changer shown on the title page. A unique feature of these small tools is that they are designed and built to withstand the temperature and vapor of steam when subjected to sterilization in an autoclave. Several of these sets are now in use and reduce materially the operating time in cranial surgery.

Portable drilling and grinding, using a high-frequency motor as the power element, became popular with industry about 1927. A standard frequency was established at 180 cycles (10,800 rpm) and a standard voltage at 1.22 volts per cycle, or 220 volts at 180 cycle. These standards automatically were accepted as a basis for development of general machine drives though the frequencies and power being used soon were far in excess of anything anticipated. This accounts for the high voltage encountered in general equipment today. The old standard ratio of 1.22 volts per cycle, or at 300 cycles 366 volts, becomes hazardous at such frequencies. This ratio probably will be lowered for the higher frequencies of 400 and 500 cycle which will be in the hands of industry in the near future, since speeds of 24,000 and 30,000 rpm are now practical, if and when required.

High-Speed Radial Drills

Ninety per cent of the holes drilled in sheet aluminum in aircraft construction are of two sizes which may be spaced over an entire sheet. Consequently, the technique used is nearly the same as in routing, namely, sheets are stacked and bolted to a table with a drill template on top with the drilling motors mounted on sliding ways, designed to be hand set and air fed. The radial drill arm illustrated in *Fig.* 6 shows twin drills mounted for operation. Drill heads are 2.5 hp, 3-phase, and 250-cycle. The small right-hand motor is wound 2-pole for a speed of 15,000 rpm with a drill capacity to one-eighth of an inch and the large left-hand unit is wound 4-pole for a speed of 7500 rpm with a capacity to five-sixteenths of an inch. Both motors slide on independent ways with separate setting and feeding mechanisms. The right handle has throttle control for air feeding the small head and the left handle for the large head. Thus the operator may drill most of the setup without stopping to change drills.

As usual in these direct high-speed drives, some small piece added to the equipment contributes to its entire success. Drill feet which move with slide feed, *Fig.* 7, and contact the material just prior to the drill point have round splined supports which telescope into the frame against a compression spring so that each foot exerts about 75-pounds down-thrust pressure against the material before drilling. This prevents vibration of the head and, most important, flutter of the stacked sheets which would result in excessive drill breakage and burred holes. This basic design of direct-drive high-frequency radial drill as standard equipment in the plants of major aircraft corporations made possible over 1000 per cent increase in production between 1938 and 1941. This view also shows an excellent comparison of horsepower to size. If both motors were wound 2-pole and operated on 250-cycle current

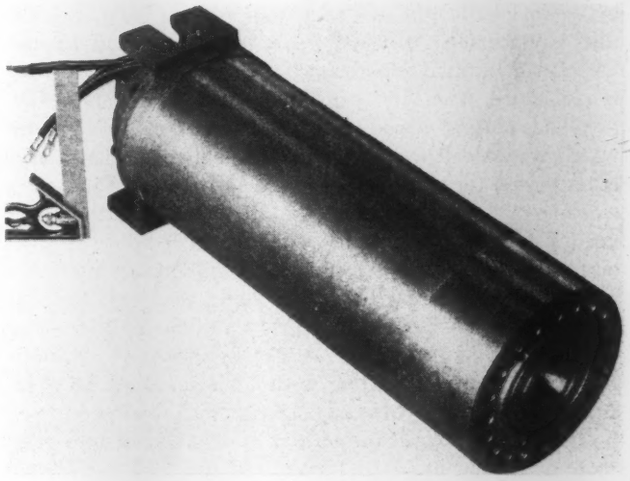
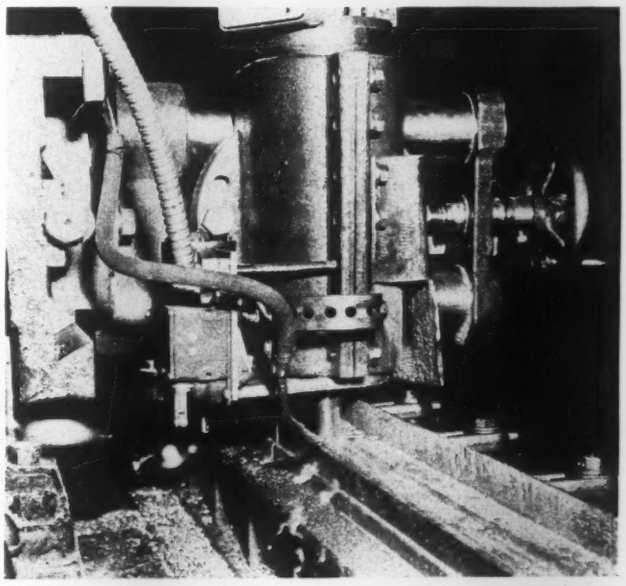


Fig. 8—Above—High cycle milling head ready for installation. Cutter mounts directly in hollow shaft. Water cooled, the head develops 15 hp on 200-cycle current

Fig. 9—Below—Special planer type extrusion milling machine with a 15,000 rpm motorized milling head—Photo, courtesy Consolidated Vultee Aircraft Corp.



(15,000 rpm), the large head would be 5 hp and the small one 2.5 hp.

High-speed direct drive is particularly efficient in all grinding operations, as the change of wheel speed is easily accomplished by an increase in frequency or the number of poles wound in the motor. An example of this adaptability is shown in *Fig.* 7. Direct driven by a 3-phase, 220-volt, 180-cycle induction motor, this grinder is rated one horsepower, weighs eight pounds, is wound two-pole, and turns 10,800 rpm with a cutting speed of 9800 linear feet per minute at the wheel. These direct drives eliminate gear weight and reduce the cost of manufacture. Rotors are mounted on two single-row, prelubricated ball bearings thus eliminating the problems of lubrication entirely.

Precision grinding is greatly improved with direct drive

by means of a motor powered with varying frequency. In this way the most efficient surface cutting speed for any wheel can be maintained until it is completely worn out. For instance, if an 18 by 1.5-inch wheel is in service and its ideal cutting speed is 6000 linear feet per minute, which would call for about 1275 wheel revolutions, there is no reason for this wheel to be discarded until it is truly worthless. Assuming that the drive motor, direct-connected, is wound 8-pole so as to deliver 5 hp on 3-phase current, and the flushing or cutting lubricant is used as a motor coolant on its path to the work, the overall dimensions of the motor could be held to a diameter of 6 inches and a length of 12 inches. Driven by means of a variable frequency changer, starting with a minimum of 85 cycle, such a motor would turn at 1275 rpm and this speed could be increased in direct proportion to wheel wear to a maximum of 190 cycle, or 2850 rpm. At this time the 18-inch wheel diameter would be worn to eight inches and ready to be discarded, but would still have a cutting speed of 6000 linear feet per minute.

Motor Becomes Milling Head

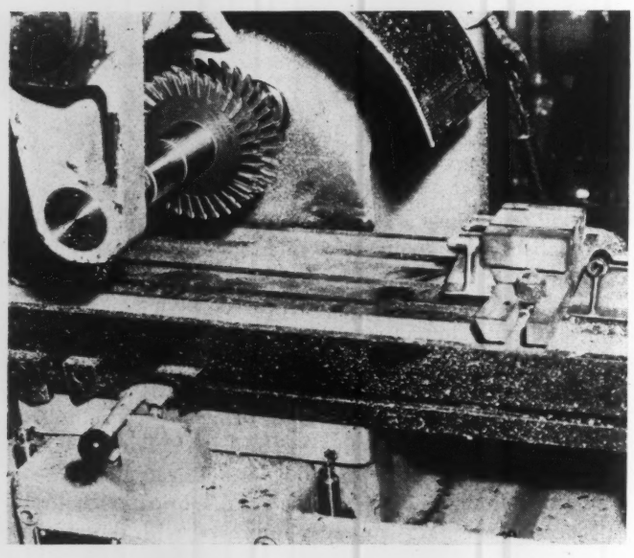
Increase in wing loading in aircraft construction necessitated the utmost strength in materials, so extruded and rolled aluminum, machined to accuracy, rapidly replaced castings. Parts cost became comparable as high-speed tools increased production. The rapid machining of these parts became practical through the development of compact motors of small diameter which operated on fixed or variable frequency at optimum speeds. Tool or cutter mounted direct to the motor shaft creates in effect a milling head which can in turn be mounted in a standard milling machine, a planer, or a special assembly for obtaining feeds, depth of cut, etc. Such a motor, *Fig.* 8, is of water-cooled construction with a hollow shaft to carry a draw-bolt for locking in place or removing the cutter. The front or working end carries a Brown and Sharpe or American Standard milling machine taper for the cutter drive and is mounted on preloaded ball bearings. Developing 15 hp on 200-cycle current with a diameter of 5½ inches and a length of 16 inches, the motor shown in *Fig.* 8 is designed especially to be assembled direct as a motorized milling head.

This unique design was developed for a particular operation on a part eighteen feet long in which a quantity of metal had to be removed from an extruded piece and held closely to dimensions. This necessitated the development of a special planer bed for length of cut and hydraulic feed for varying the depth of the cut, controlled by a template of irregular shape. When completed, this machine removed three cubic inches of material per horsepower per minute. Shown on the planer in *Fig.* 9, the motor is operated on a set frequency of 250 cycles (15,000 rpm), cutter diameter being constant.

Immense increase in production afforded by this first experimental planer called for further adaptation of the same type of motorized cutter heads to machines of standard design with established traverse feeds and stops. This proved an easy problem, as the motor diameter was of such size that with a few changes it could be clamped in the place of the bearing assembly on a standard milling machine without affecting the design of the table feed and outboard bearing arrangements as manufactured. However, differences in the type of parts manufactured required deep clearances and various diameters of cutters. This necessitated more torque as lower frequencies were used. Motor horsepower was increased one-third by lengthening the stack and entire housing about six inches, the design remaining otherwise unchanged.

Each of these motor installations is powered with a 25-kva variable frequency changer, having an output of 70 to 250 cycles, mounted on a platform above the machine. Current frequency is varied by the operator with a remote control at the mill so that changes in diameter of the cutter, can be compensated for by increasing or decreasing the speed without loss of time.

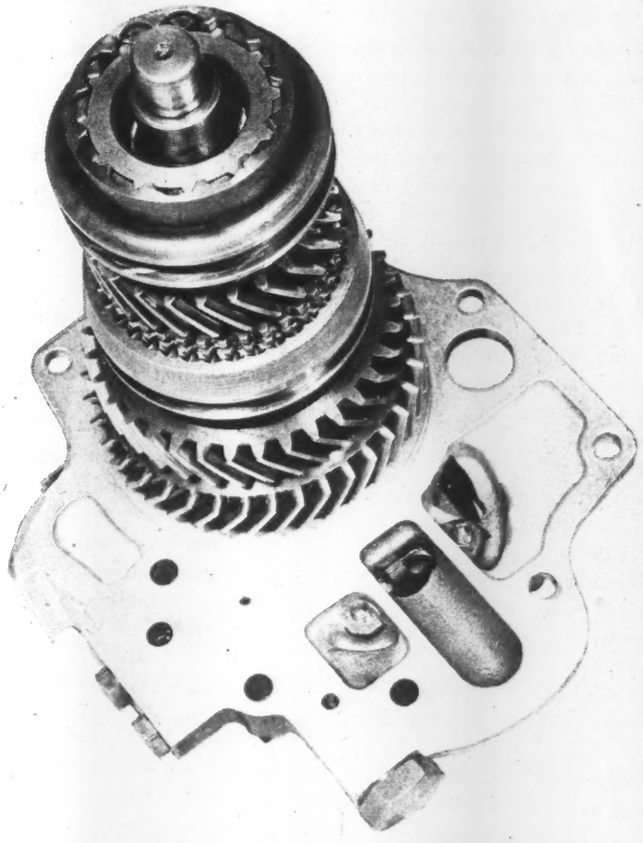
Fig. 10—Below—Standard milling machine with 12,000 rpm high-cycle drive motor replacing conventional drive —Photo courtesy Douglas Aircraft Co. Inc.



Tremendous Increase In Production

Various types of direct motor drives which have proved the practical solution for the machining of aluminum have amazing cutter speeds, sometimes exceeding 9000 linear feet per minute. In the past few years these speeds have increased production of machine parts made from aluminum and similar materials over fifteen hundred per cent in some instances. In *Fig.* 10 is illustrated a typical milling machine with a water-jacketed, variable-frequency drive motor in the place of the regular mill drive. Outboard bearing of the machine is replaced with a prelubricated ball bearing, seal-protected in a container. Operating speeds up to 12,000 rpm are available.

All in all, the experience that has been gained indicates the probable use of high frequency with geared reductions wherever low speed and high torque with a wide range of spindle rpm is required or where a small, compact motor is essential for mounting on the machine itself. It is altogether likely that in the near future several well-known machine tools will be presented to the trade with these principles incorporated as primary features.



Trends in Automotive Transmissions

By Colin Carmichael
Associate Editor, Machine Design

Part I

IN the interests of greater safety and improved car performance designers have for many years sought to simplify the operation of shifting gears, and notable advances have been made. The present article reviews recent and current developments in automatic and semiautomatic transmissions and attempts to forecast possible future trends. It is hoped that designers of other types of machines will find useful ideas in the operating principles of the transmissions here discussed and at the same time will be aided in their evaluation of new cars as they

appear on the market.

Before discussing the details of the transmissions themselves it should, perhaps, be pointed out that their function is that of torque conversion rather than simply speed changing. They are a necessary adjunct to the high-speed internal combustion engine due mainly to the wide range of wheel torques required in road operation and also to the falling off in torque output at low engine speeds, *Fig.* 1. Should engine speed on a heavy pull (acceleration or hill) drop below that at which maximum torque is produced, a good transmission should permit a downshift that will bring engine speed up to the speed of maximum power. In the example shown, intermediate gear ratio therefore should be 3700/2100 = 1.76. Although in shifting, engine torque drops from 146 to 121, transmission output rises to 121 x 1.76 = 213 ft-lb. Likewise in dropping from intermediate to low the ratio would again be 1.76, so that the actual ratio in low should be 1.76 x 1.76 = 3.1. While the foregoing is not necessarily followed exactly, for various reasons, it forms the underlying principle in the selection of ratios.

It may be said that the present-day standard type of 3-speed transmission attempts to minimize gear-shifting effort by three means: (a) Employment of an engine large enough to make gear changing an infrequent necessity, (b) employment of synchro-mesh mechanism for shifts between high and intermediate ratios, to simplify shifting and (c) employment of an intermediate ratio large enough to permit starting from a standstill without having to go into low. The last-named expedient, which permits two-speed operation for all normal driving conditions, cannot be said to be entirely satisfactory with a friction clutch, but performance is greatly improved when a fluid coupling is interposed between the engine and transmission.

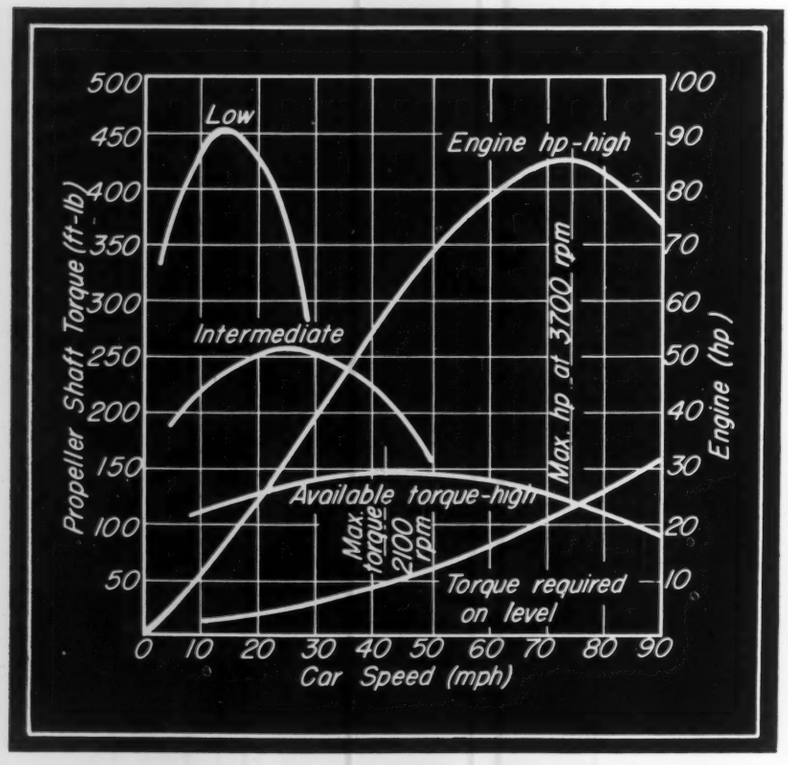


Fig. 1—Curves show torque available in high, intermediate and low gears compared with torque required to drive car along smooth level pavement in still air. Vertical distance between "available torque" and "torque required" curves represents margin for acceleration, hill climbing, soft roads, head winds, etc. Figures are typical of present-day cars in low-price field

To eliminate the manual shifting and clutch pedal operation, two broad types of transmissions may be used:

(a) Selective speed transmissions with automatic controls

(b) Torque-responsive converters whose speed ratio changes automatically with load.

Selective speed transmissions, which find their chief applications in passenger cars, will be discussed in the present article. In a subsequent article the characteristics of the automatic torque converter, which is being applied extensively to busses, will be covered.

A step toward the automatic shift, with the objective of improved economy rather than ease of driving in traffic, was the automatic overdrive. This was an adjunct to the conventional transmission and permitted the engine to run at a lower speed than the driveshaft. The shift would occur above a certain car speed whenever the operator momentarily released the pressure on the accelerator control pedal.

It has been noted that with present-day large engines and fluid couplings, a two-speed transmission satisfactorily fulfills all normal requirements. The simplest form of automatic transmission, therefore, would be one in which automatic controls were added to a conventional gearbox for shifting betweeen high and the next lowest gear. This idea, with some important modifications, forms the basis of the Chrysler and DeSoto transmission.

A schematic cross-section of this transmission is shown in *Fig.* 2. Four speed ratios are possible, with automatic shifting in either of two ranges—between low and second or between third and high. The operator selects manually the desired driving range, after which shifting is automatic between the two selected speeds according to the speed of the output shaft.

Referring to *Fig.* 2, power from the engine is applied at the input end through a fluid coupling and friction clutch. In high range the manually controlled synchronizer sleeve is in forward position so that the output shaft on which it is splined turns at the speed of gear *C*. In low range the synchronizer sleeve is to the rear, compelling the output shaft to turn with gear *E*. In either of these ranges the hydraulically controlled synchro clutch operates automatically either to couple directly or to disconnect gears *A* and *C*. When in the position shown, gears *A* and *C* are declutched and the power goes through the countershaft gear *B*. This gear drives the countershaft proper through a free-wheeling clutch. When the synchro clutch is moved forward,

a sleeve on the countershaft disengages the free-wheeling clutch, rendering it inoperative regardless of load direction. Reversing is manually obtained by sliding the reverse idler *H* into engagement with gear *G*. TABLE I summarizes the power flow and includes the gear ratios.

TABLE I

Gear Ratios for Chrysler Transmission

Gear	Synchro Clutch	Synchronizer Sleeve	Gear Trains	Gear Ratio
Low	Rearward	Rearward	ABFE	3.57
2nd	Forward	Rearward	ACDFE	2.04
3rd	Rearward	Forward	ABDC	1.75
Direct	Forward	Forward	AC (direct)	1.00
Reverse	Rearward	Neutral	ABFHG	—3.99

About 95 per cent of the driving can be done in the high range (third and direct) with the low range as a reserve when greater torque is needed or as an aid to maneuvering in close quarters. In the low range, automatic shifting occurs at about 6 mph. In the high range, upshift from third to direct occurs at any speed above 11 mph whenever foot pressure on the accelerator pedal is eased momentarily. Downshift from direct to third occurs automatically at speeds below 14 mph, but may be effected at any speed below 45 mph whenever the driver desires, by means of a "kickdown."

Control of the automatic shift is effected hydraulically, power being taken from a Gerotor pump driven by the output shaft. Basic principles of the control are illustrated schematically in *Fig.* 3, which shows the synchro clutch disengaged, as it would be in third or first speed. As car speed increases, movement of the governor weights (which revolve at a speed proportional to countershaft speed) allows the governor points to open, de-energizing the relay coil and allowing both relay points to open. This breaks the solenoid circuit, de-energizing that unit and allowing the pilot valve to be pushed up by the action of a spring. As a result, oil pressure now flows through the pilot valve to the underside of the main valve, pushing it up and permitting oil at 50 psi to flow behind the piston which compresses the engaging spring and the return spring. The engaging spring imposes a force on the shifter fork sufficient to move the synchro sleeve whenever the transmitted torque is momentarily eased by releasing the accelerator pedal. Until the torque is eased, permitting synchronization of pinion and synchro-sleeve speeds, a blocker ring positively prevents engagement. This blocker ring may be seen in the head illustration, which shows the main shaft assembly of this transmission.

After the shift has occurred, the synchro sleeve will remain engaged so long as car speed is high enough to keep the governor points open. When car speed drops, the governor points again close, grounding the circuits and energizing the relay coil and closing both relay points. As a result the solenoid is energized once more and pushes the pilot valve down, which releases the oil pressure below the main valve and allows it to be pushed down by the spring. This releases the oil behind the piston and permits the return spring to move the piston back against the rail shoulder. In this movement of about $\frac{7}{8}$-inch, the engine ignition is interrupted by the closing of the points in the interrupter switch just above the piston. This momentary cutting of the ignition eases the transmitted

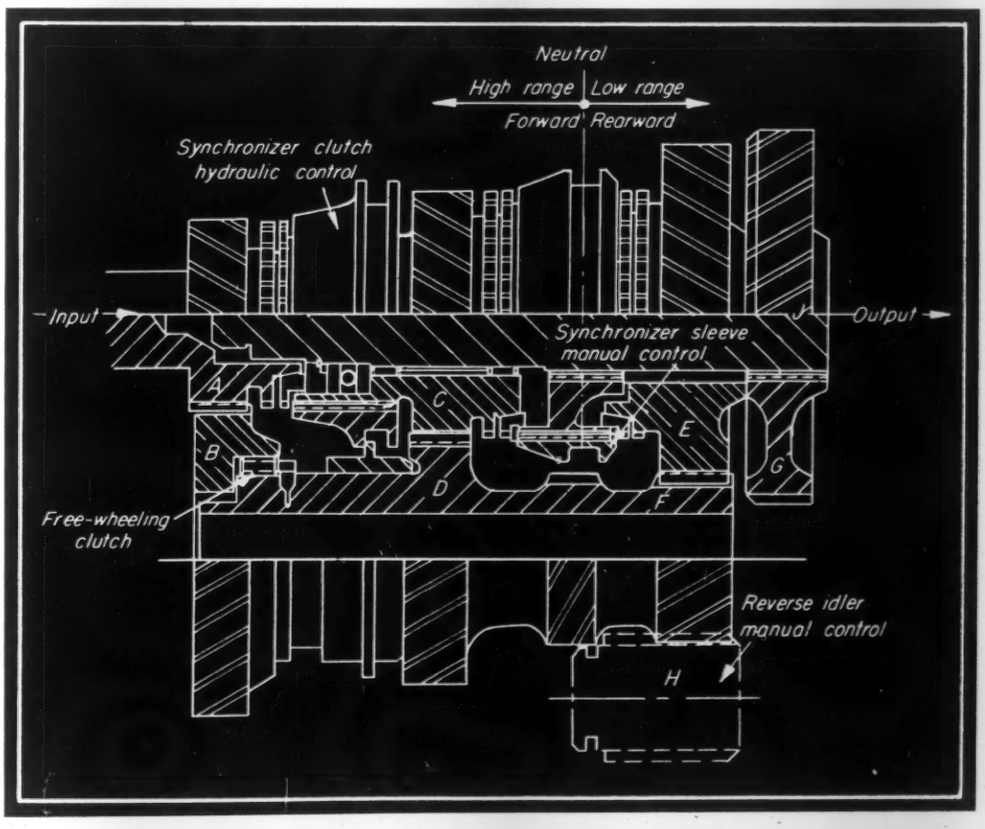


Fig. 2—Schematic diagram shows arrangement of gears and sliding synchronizer sleeves for Chrysler four-speed transmission having automatic shift in either of two speed ranges—high and low

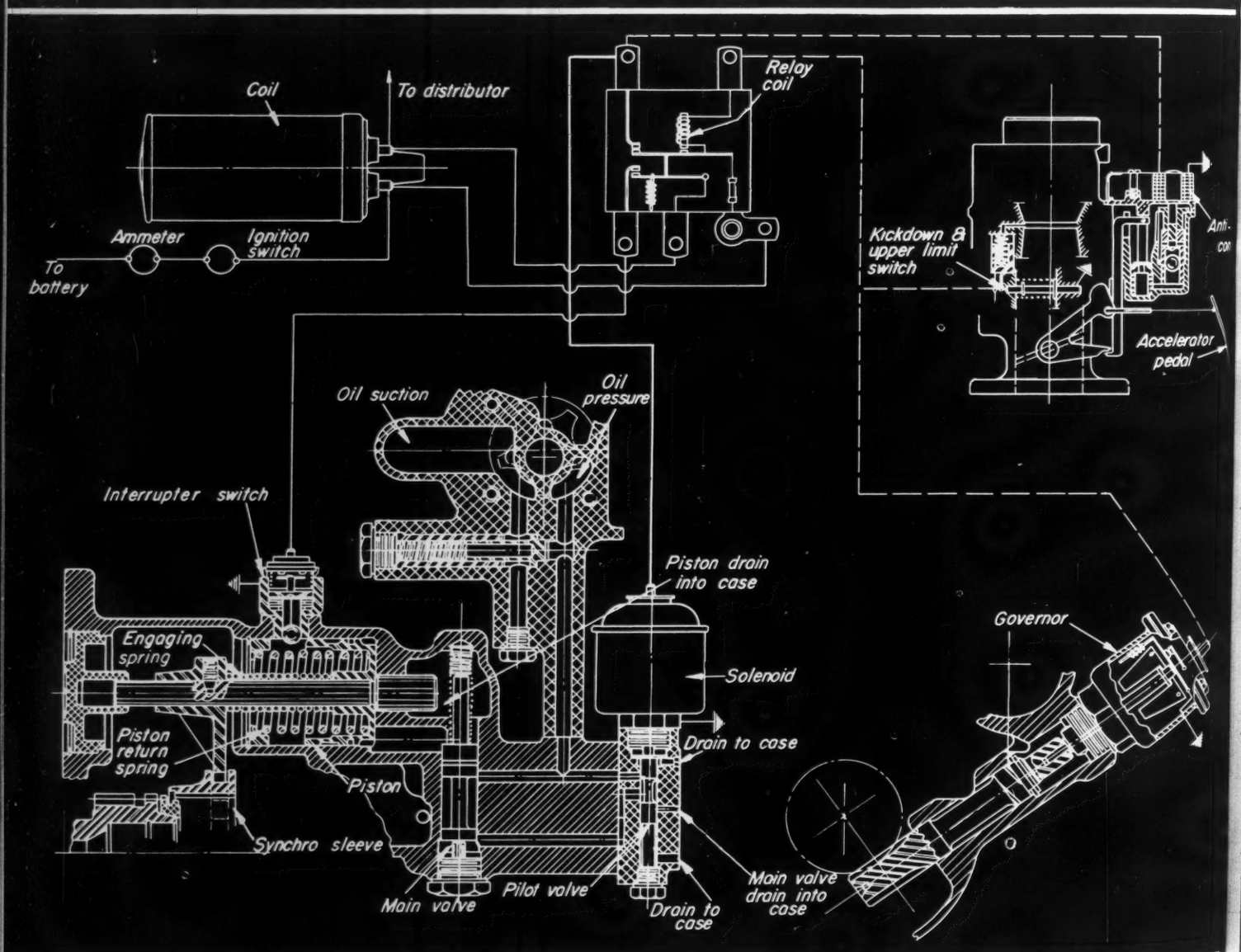
torque and allows the synchro sleeve to move out of engagement with the pinion, under the influence of the return spring pressing against the piston and the rail shoulder.

Should the driver wish to drop to third gear at some speed above 14 mph (when the governor points open) as might occur, for instance, in pulling out from behind a truck when fast acceleration is needed, he can do so by depressing the accelerator pedal beyond the normal position, thereby closing the kickdown switch. This switch is located at the carburetor and grounds the circuits in exactly the same manner as the governor points, so that the same sequence of operations occurs as outlined in the preceding paragraph. Kickdown is effective only up to 45 mph, above which speed a spacer point in the kickdown switch is pulled out of position by a vacuum-controlled plunger operated from the carburetor venturi. Venturi vacuum is a function of air flow into the engine and is high enough at 45 mph to pull up the spacer, preventing the establishment of ground.

Although ignition is momentarily cut on downshifts by the interrupter switch, which is controlled by the piston movement, this does not occur on upshifts. The reason is that the governor points are open, therefore the relay coil is de-energized, leaving its points open and making it impossibe for the ignition interruption circuit to ground.

In the transmission discussed in the foregoing, speed of the output shaft is the only factor controlling the point at which shifting can occur. However, delayed upshift and the kickdown give the driver a measure of control to meet conditions where load also is a factor. To provide a fully automatic control in which both load and speed affect the point at which shift occurs, an oil pressure must be furnished which is proportional to load on the engine and

Fig. 3—Electrical and hydraulic control circuits for automatic shifting of transmission shown in Fig. 2



which opposes that due to the speed governor. This requires a more elaborate setup, and is the basis of control in the Hydra-Matic drive on Cadillacs and Oldsmobiles.

Shown schematically in *Fig.* 4, the Hydra-Matic drive consists of three planetary units—front, rear and reverse—together with a fluid coupling and a hydraulic control circuit. Power from the engine flows first to the ring gear of the front unit, which is a simple planetary reducer. The sun gear of this unit is integral with a brake drum and the output power is taken from the planet cage. With the brake on, the front unit transmits a reduction of 1.45 to 1, while with the brake released and the sun gear locked to the planet cage by means of a clutch, the ratio is 1 to 1. The planet cage is connected to the impeller (driving element) of the fluid coupling and also—through a clutch—to the first ring gear of the rear panetary unit. Runner (driven element) of the coupling is connected to the sun gear of the rear unit. Although shown in *Fig.* 4 as a compound unit, the rear unit in 1946 cars is a simple planetary reducer, the output of which is taken from the planet cage. With the brake, which is integral with the first ring gear, applied and the clutch released, all the power flows through the fluid coupling and the sun gears, the speed reduction being 2.63 to 1. When the brake is off and the clutch is applied, connecting the first ring gear directly to the output of the front unit, power flows into the rear unit both from the sun gear and the ring gear, the ratio being 1 to 1. Approximately 60 per cent of the torque is transmitted directly through the ring gear and 40 per cent through the fluid coupling to the sun gear. This condition exists in third and fourth gears and has the effect of reducing slip at the fluid coupling. TABLE II summarizes the power flow conditions.

TABLE II

Gear Ratios for Hydra-Matic Drive

	—Front Unit—		—Rear Unit—		Gear
Gear	Brake	Clutch	Brake	Clutch	ratio
1st	On	Released	On	Released	3.82
2nd	Off	Applied	On	Released	2.63
3rd	On	Released	Off	Applied	1.45
4th	Off	Applied	Off	Applied	1.00

Reverse is obtained by locking the ring gear of the reverse unit, the front and rear units being operated as if in third gear except that the rear clutch is released. This gives an overall ratio of —4.3.

As shown schematically in *Fig.* 4, the brake bands and clutches that effect the speed changes are operated by hydraulic pressure. The controls consist of a set of three shift valves (one for each shift), whose positions are influenced by two opposing hydraulic pressures—one responsive to car speed and the other to throttle opening. Normally all shifting, both up and down, is fully automatic. A forced downshift, or kickdown from fourth to third, may also be effected at the will of the driver by pushing the accelerator beyond full throttle position.

It is of interest to note that the Hydra-Matic drive was used extensively during the war on the M-5 and T-24 light tanks, as well as for many other military vehicles, including much larger tanks which required specially designed units of greater capacity. In spite of its seeming complexity, therefore, this type of drive appears to possess the necessary

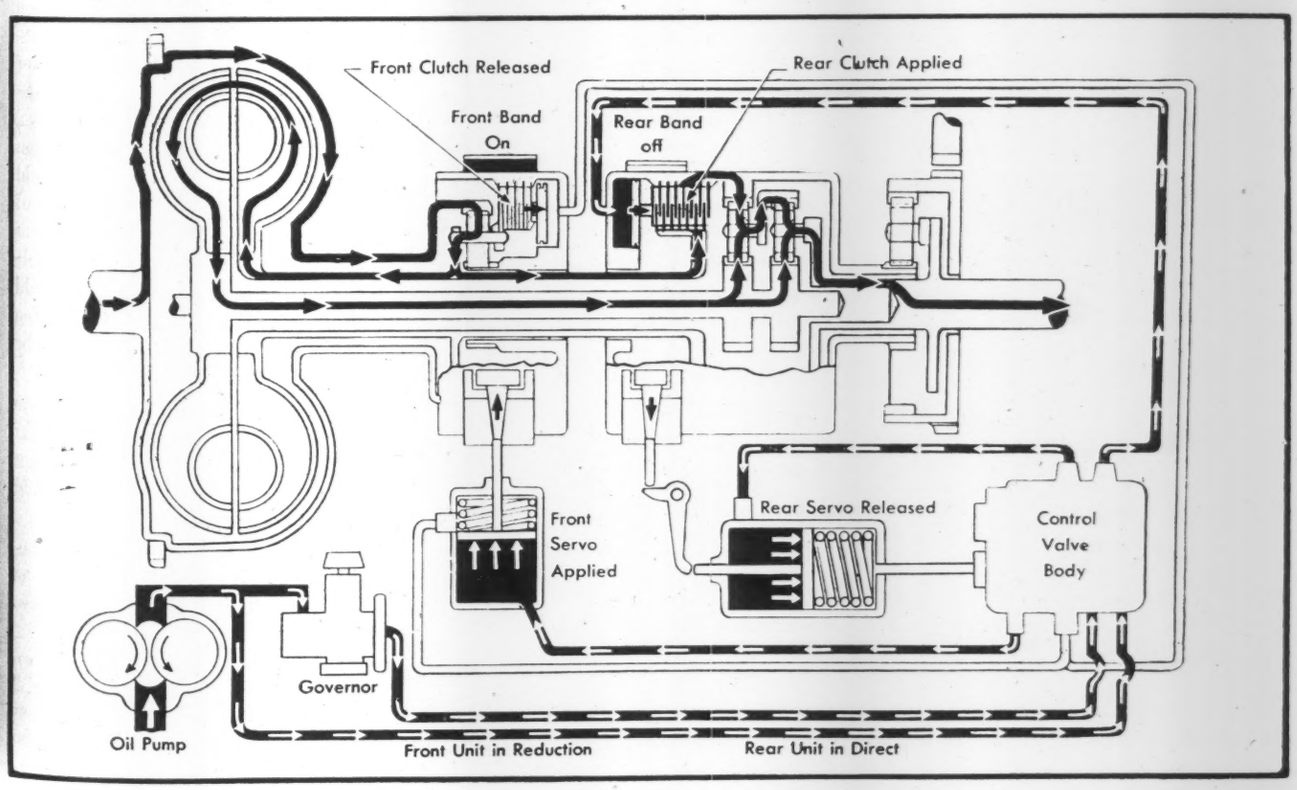


Fig. 4—Schematic diagram showing principal units of the Hydra-Matic transmission. Arrows indicate power flow in third gear. Front unit is in 1.45 reduction, rear unit 1:1

reliability for passenger-car work.

Transmissions used on passenger cars in actual production so far have utilized purely mechanical means for effecting speed or torque conversion. Designers have for many years attempted to develop satisfactory hydraulic or electric drives possessing the desirable features of infinitely variable ratio. Reference to *Fig.* 1 will show the advantages of such a stepless change over the conventional three or four-speed ratios: It means that maximum torque can be available at all speeds without a pause for shifting, with consequent improvement in pickup and hill climbing.

At the same time, with the proper automatic controls the speed ratio could be adjusted so as to give an economical "load factor" on the engine. Referring to *Fig.* 1 load factor for level road operation would be the ratio of "torque required" to "available torque." For the average engine, minimum specific fuel consumption is obtained when this factor is about 0.8. Below this value the frictional torque of the engine is an unduly large proportion of the power developed. With the ideal infinitely-variable transmission and the proper controls it should be possible to adjust the ratio automatically to maintain close to 0.8 ratio except under special conditions when full torque is desired. This and other characteristics of an ideal transmission were discussed in more detail in a paper by W. S. James of the Ford Motor Co. at the SAE annual meeting, January, 1946.

Possibilities of the All-Hydraulic Drive

Turning to the industrial field for ideas on infinitely variable speed control, designers naturally are intrigued by the possibilities offered by the variable-delivery hydraulic pump. It is easy to visualize what a sweet transmission would result from the combination of such a pump, driven by the engine, and a hydraulic motor on each wheel. The clutch and differential could be eliminated and all ratios would be available both in forward and reverse operation. Proper valving would take care of necessary speed differentials in rounding a curve, while the combination of a governor responsive to car speed and an opposing effect proportional to throttle opening, as in the Hydra-Matic drive, would automatically adjust the pump delivery to give the ideal speed ratio. An alternative would be to use a constant-delivery pump with variable-displacement motors. Compared with a purely mechanical drive such an arrangement, with hydraulic units hitherto available, is handicapped by lower efficiency—due partly to losses in the hydraulic lines—and greater weight and cost. However, there is considerable activity in this field and it is possible that an all-hydraulic drive may soon appear.

A simpler and less expensive hydraulic drive would result if instead of a variable-delivery pump two constant-displacement engine-driven pumps were used. By suitable valving automatically controlled by speed and load, the delivery of either one or both pumps could be supplied to the wheel motors. For example, if the relative outputs of the two pumps were 1 and 1.6, three ratios in geometric series would be possible, namely, 1, 1.6 and 2.6. While such an arrangement would not provide the infinitely variable ratio it could, at some sacrifice in economy, do so by suitable by-pass valving. On the other hand it may be argued that, inasmuch as the step change is satisfactory on present-day cars, there may not be a real necessity for infinitely variable ratios. The smoothness of the hydraulic drive and the ease of control may inspire some manufacturers to put out a car with this type of drive, perhaps using more than two pumps, so as to extend the number of ratios. For example, three pumps of relative capacity 1, 1.6 and 4.2 would give five ratios in geometric series: 1, 1.6, 2.6, 4.2 and 6.8. By using other combinations of pairs of pumps, two additional ratios, 5.2 and 5.8 would be available. With the larger number of steps, the transmission would begin to approach the infinitely variable ideal. The pumps for such an arrangement could well be of a less expensive type than the variable delivery.

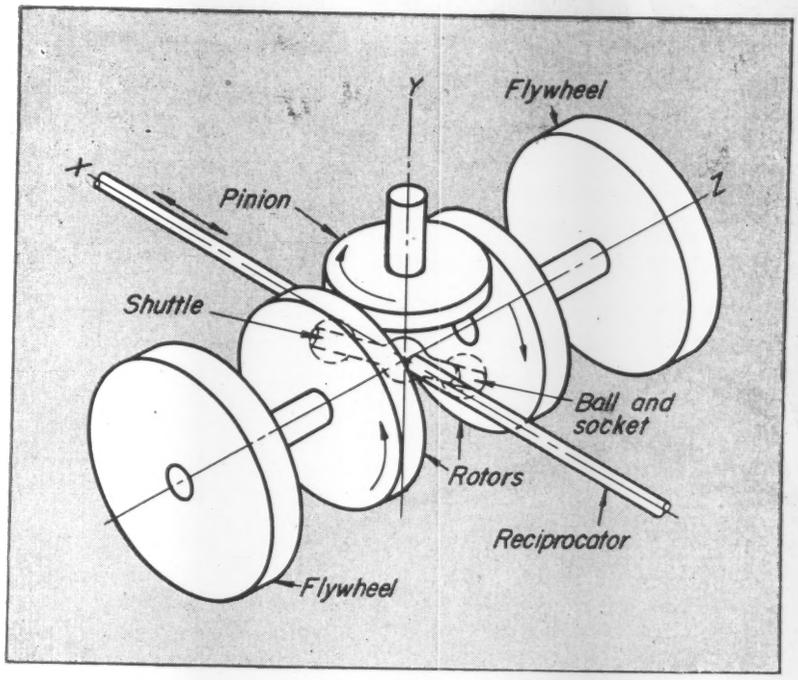
There remains the possibility of an all-electric transmission, which would perform in a similar manner to a hydraulic drive. With a direct-current engine-driven shunt generator and individual series motors on the wheels an infinitely variable ratio is obtainable. Automatic control could be made responsive to car speed and engine load, and the setup would be comparable to the hydraulic drive with a variable-delivery pump. Again, efficiency, weight and cost of standard long-life industrial types of equipment are factors against such a drive for passenger cars. However, recent advances in the design of electric motors and generators and the use of improved insulating materials make an electric drive entirely possible in the future. By designing the electrical components for no more than the usual 2000 to 4000 hours life of the car, weight and cost could no doubt be drastically reduced.

Development in high-cycle electrical components for aircraft suggest the use of an alternating-current drive. However, it is to be noted that motor speeds should be nearly synchronous for high efficiency, which presents difficulties in arranging an infinitely variable ratio. There might perhaps be possibilities in a multi-pole motor on which the number of active poles could be changed by de-energizing certain ones. For example, an 8-pole motor could operate with 8, 6, 4 or 2 poles active. To provide high frequency the engine-driven generator could have, say, 12 poles, giving 400 cycles per second at 4000 rpm engine speed. Assuming that normal high gear would be obtained with 4 poles active on the motors, top speed of the motors would then be 12,000 rpm necessitating a gear reduction of about 12 to 1 at the wheels. The 2-pole condition would be equivalent to an overdrive and would permit low engine speed and high economy at cruising speeds. Alternatively active generator poles could be changed and the number of motor poles fixed.

As with other fully automatic drives, control of the ratio on an electric drive could be made responsive to both car speed and load on the engine. Inasmuch as ratio changes merely involve switching operations, the controls could be relatively simple and might be all-electric.

In a subsequent article the application of torque-responsive converters will be discussed. While such units so far have been used only in busses, they offer attractive possibilities for passenger-car use.

MACHINE DESIGN acknowledges with appreciation the cooperation of the Chrysler Corp. (head illustration and *Fig.* 2 and 3) and the Cadillac Motor Car Div. of General Motors Corp. (*Fig.* 4) in furnishing information and illustrations included in this article.



Novel Reciprocating Drive Gives Harmonic Motion

DESIGNED to eliminate piston side thrust and to make possible more compact units for the conversion of rotary to rectilinear reciprocating motion or vice versa, a novel motion transformer, shown schematically in the head illustration, has recently been developed. This mechanism consists of the following essential elements: (1) A reciprocator which travels in a straight line, (2) a shuttle mounted on the reciprocator using bearings capable of taking thrust, (3) two*

This article is based on a research report of the Office of Production Research and Development, War Production Board, Washington, D. C. Inventor of the motion transformer is James A. Hardman of Logan, Utah. All patent rights on the mechanism have been assigned to Utah Scientific Research Foundation.

*The device may be constructed with only one rotor in which case the reciprocator would have force components acting on it at right angles to its axis.

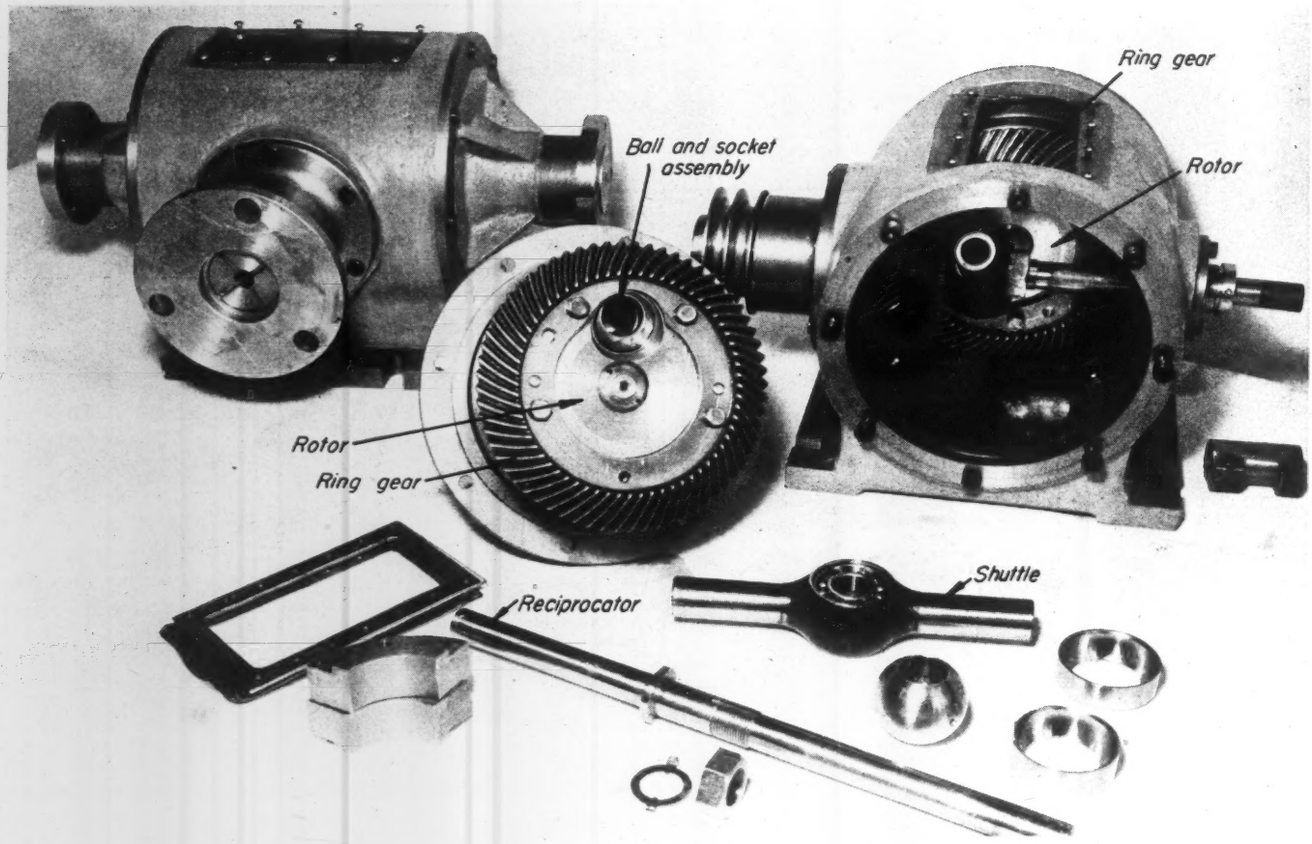
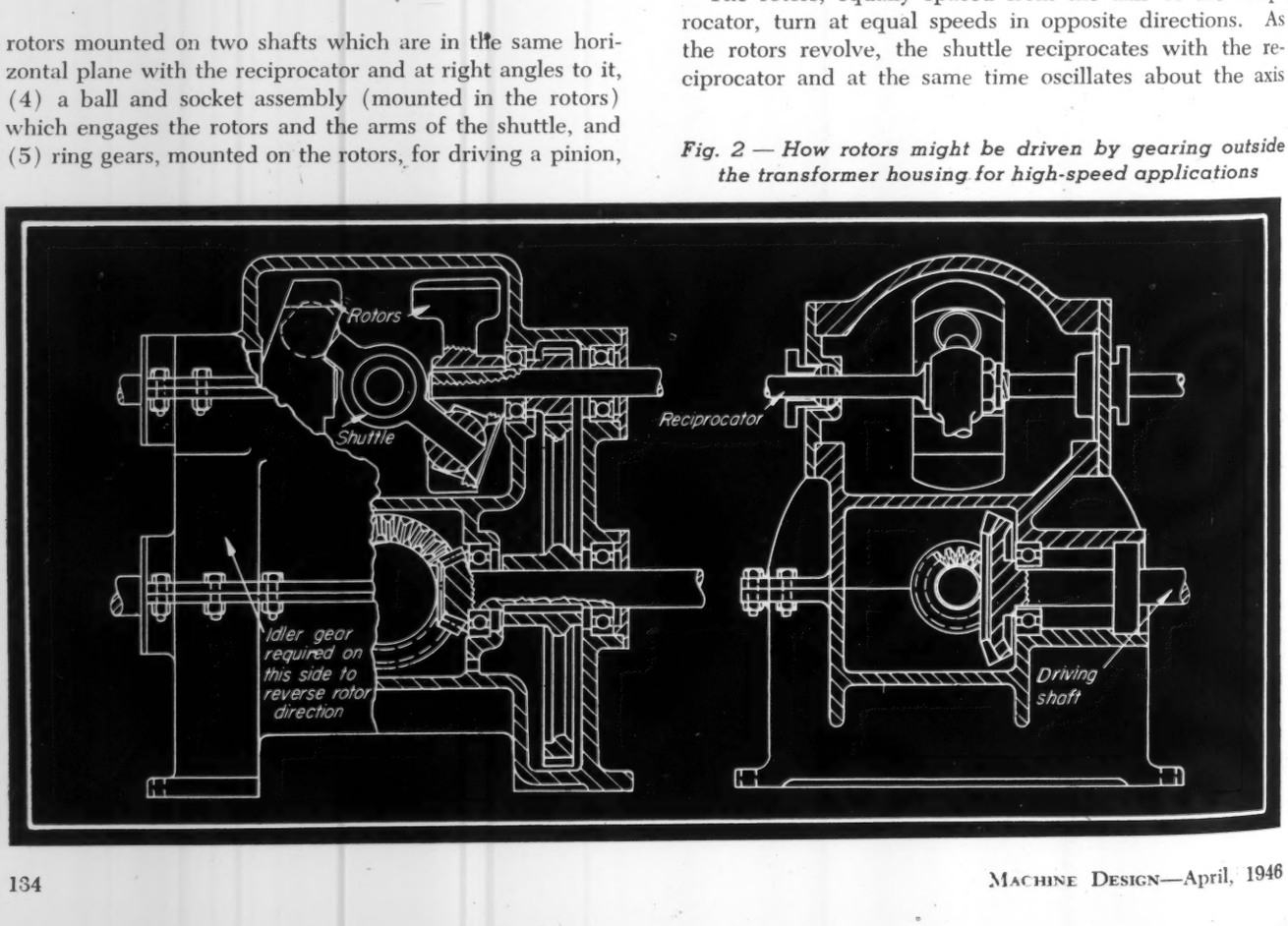


Fig. 1—Partially disassembled motion transformer, showing various components and how unit is constructed

rotors mounted on two shafts which are in the same horizontal plane with the reciprocator and at right angles to it, (4) a ball and socket assembly (mounted in the rotors) which engages the rotors and the arms of the shuttle, and (5) ring gears, mounted on the rotors, for driving a pinion, or being driven by a pinion.

The rotors, equally spaced from the axis of the reciprocator, turn at equal speeds in opposite directions. As the rotors revolve, the shuttle reciprocates with the reciprocator and at the same time oscillates about the axis

Fig. 2 — How rotors might be driven by gearing outside the transformer housing for high-speed applications



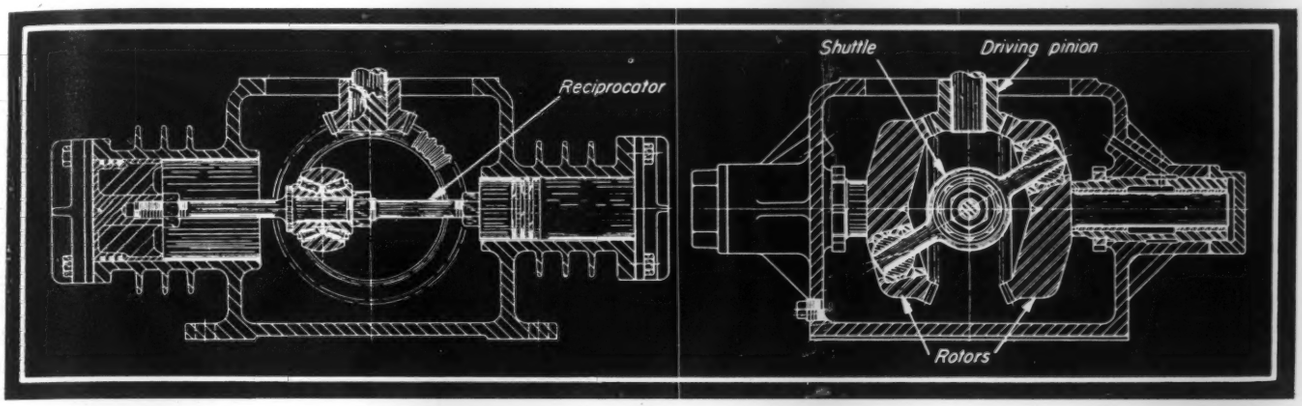


Fig. 3—New motion transformer driving the pistons of a 2-cylinder, 2-stage, air-cooled compressor

of the reciprocator. The reciprocating motion of the shuttle is transferred to the reciprocator through thrust bearings. As the shuttle oscillates, its arms slide simultaneously through holes in spherical balls mounted in sockets which in turn are mounted in the rotors. Centers of the spherical balls are equally spaced from the reciprocator and rotor axes. The partially disassembled test model, *Fig.* 1, shows the various parts.

If the rotors revolve at constant angular velocity, the motion of the reciprocator is simple harmonic and there are no force components acting at right angles to the axis of the reciprocator, provided alignments are perfect. Since the direction of motion of the reciprocator is in the plane of the rotors which cause its motion, it is never possible to have absolutely constant angular velocity of the rotors; that is, it is necessary to provide inertial forces by slowing the rotors down to carry the reciprocator beyond the dead points at each end of its stroke. Consequently the motion of the reciprocator is not absolutely simple harmonic. However, with adequate flywheels on the rotor shaft, speed variations are so small that the reciprocator describes what is practically simple harmonic motion.

Motion of each spherical ball has three components with respect to fixed space: (1) Revolution in a circular path by virtue of its being in the rotor, (2) oscillation in its socket due to the oscillation of the shuttle, and (3) revolution about the axis of the shuttle arm. This latter motion, due to the difference in frictional drag between the ball and socket and the ball and shuttle arm, is of an indeterminate nature.

Motion may be imparted to the rotors, or taken from them, either by the ring gears mounted on the rotors with a pinion between them or by gears on the rotor shafts outside of the main motion transformer housing, *Fig.* 2. The latter arrangement is probably the better for the higher speed applications and for cases where it is advisable to lubricate the gears with a lubricant different than that for other enclosed moving parts. In this connection it is notable that all enclosed moving parts may operate in a lubricating bath. The second arrangement would require an idler gear between one of the rotors and the main drive (or driver) shaft. In either arrangement the motion transformer unit may be designed to act as a speed increaser or reducer by control of gear ratios. Power may be applied to or taken off the ring gears anywhere on their circumference.

An air compressor which employs the new motion transformer is shown in *Fig.* 3. The pistons move in straight-line motion, are free of side thrust, and thus require only a minimum length.

The stub-shaft method shown in *Fig.* 3 for mounting the rotors in the housing is simple and inexpensive. It is intended in this design that the rotors shall be assembled though the hole in the top of the housing which is provided for the vertical motor base mounting. Sleeves, threaded on each end, and removable from the bosses on either side of the housing, provide bearings for the rotors. Inasmuch as the rotors are identical, they are interchangeable and only one type rotor for each desired size of compressor need be manufactured. By making the relative

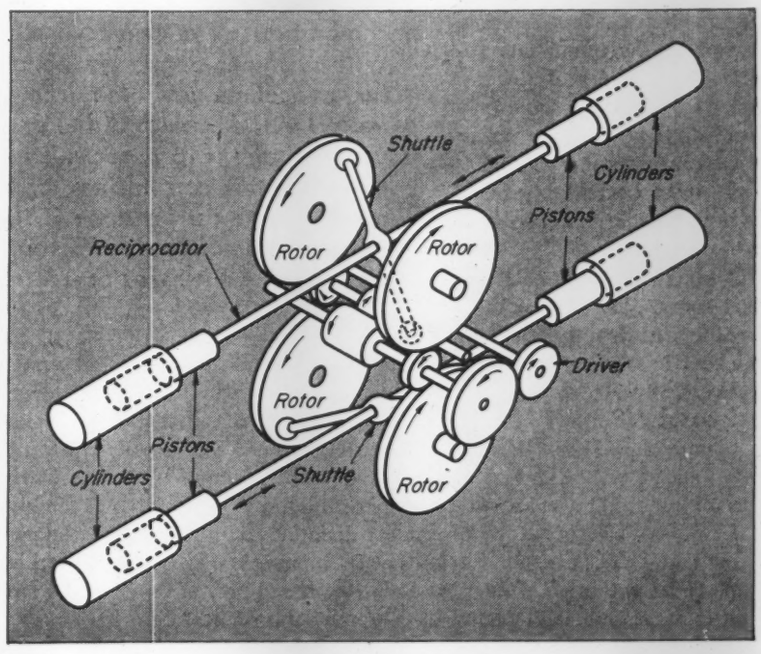


Fig. 4—Right—Schematic drawing shows how two motion transformers might be used in a 4-cylinder, single-acting power pump

position of the socket and the rotor teeth the same in all cases and by using a pinion with an even number of teeth, the synchronization of the rotors is automatically established. Meshing of the pinion teeth with the rotor gears is foolproof once the shuttle is mounted. As has been indicated, in this design wrist pins and their associated bearings are eliminated.

Schematic drawing, *Fig.* 4, shows how the new motion transformer could be used in an opposed type, four-cylinder, single-acting power pump. Exacting needs in the field of reciprocating pumps for increased pressure and the handling of fluids containing abrasives, as in the case of slush pumps and cement pumps, are generally met by the use of the plunger type pump. The plunger type pump is a single-acting mechanism, and where the plunger cannot carry side-thrust pressure, each plunger in a pump of the crank and connecting rod design requires a guided crosshead.

In the pump of *Fig.* 4 power is imparted to the rotors through spur gears, the reversed direction of rotation of the rotors being accomplished by the use of an idler gear.

In the case of steam engines, a motion transformer having a sine curve characteristic, or simple harmonic motion, will enable a designer to make a steam valve which will cut off at equal points at both ends of the cylinder and also at equal points with regard to the crank shaft revolution. The new motion transformer also affords a design which is considerably more compact than the conventional crank, connecting rod and crosshead, for either single-acting or double-acting pistons.

Atomic Power in Peacetime

By C. G. Suits

Vice President & Director of Research
General Electric Co., Schenectady, N. Y.

SINCE August 6, 1945 there has been much speculation about the peacetime uses of atomic, or nuclear energy. Proposed uses range from automotive power plants, through ship propulsion, to interplanetary rockets. If one weights all of the doubtful physical and chemical factors heavily on the optimistic side and neglects the economic factors completely, very few of these applications can be ruled out entirely. Which of the possible applications of nuclear energy is likely to become practical, and when, depends upon the amount of research, development, and engineering effort which can be devoted to these physical factors in the immediate future. The object of this article is to consider some possible applications of nuclear energy, and to illustrate what steps must be taken, primarily in research, to bring them into reality.

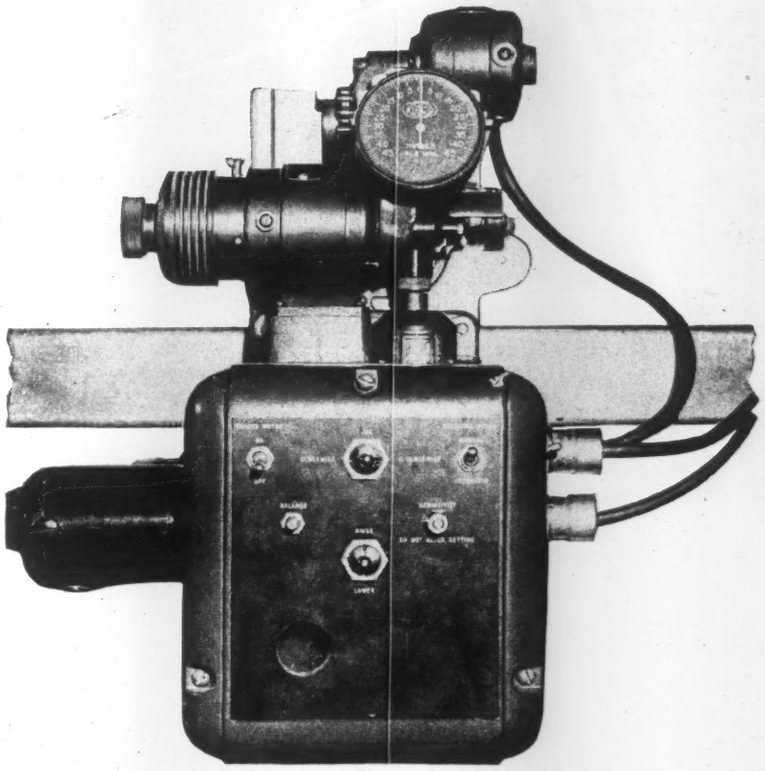
WILL ATOMIC FISSION displace chemical combustion as a primary source of power? Will machines ultimately be able to harness for peacetime uses the tremendous energy locked in the nucleus of the atom? In a sober analysis of the prospects, Dr. Suits recently told the American Institute of Electrical Engineers what must be done if these things are to be accomplished. This article is based on his talk, which was presented in New York

The basic physical fact that energy may be produced by the disintegration of the nucleus has been known since the discovery of natural radioactivity 50 years ago by Becquerel. Many years ago, one could get a very large number of kilowatt-hours from a pound of radium. The trouble is that radium did not then, and does not now, come by the pound. It comes by the milligram, at a price of $20.00 per milligram.

Discovery of a new type of nuclear disintegration called fission, in 1939, *is* new. Fission occurs in uranium, thorium, and some other elements. Relative to radium, uranium is an abundant element. It comes by the pound and costs a few dollars per pound. Only the isotope U235 undergoes fission and it represents less than one per cent of natural uranium. However, under the most favorable circumstances the bulk of natural uranium, suitably purified, is converted to fissionable elements, so that nearly all of it may be used to create nuclear energy. The fission of one pound of U235 produces ten million kilowatt-hours.

Uranium in a pure condition, or enriched in the isotope U235, may be used in a chain-reacting pile to produce controllable heat energy. This nuclear reaction in a pile goes at any temperature permitted by the materials of construction, which include the fissionable elements, the moderators (slower-downers), the heat transfer medium, the various mechanical parts required for control, and finally the radiation shield. During operation the fissionable material is slowly used up; nuclear reaction products, some of them toxic gases, accumulate; operating personnel must be shielded from very intense radiation, especially neutron radiation accompanying the reaction. Because of a surface-to-volume effect, the pile must contain a certain minimum quantity of fissionable material to react satisfactorily. The whole mechanical assembly required for a chain reacting pile, and some of the problems of operation, becomes analogous to a stoker-fired boiler. The fissionable material or fuel must be fed in, the reaction products or ashes must be removed, the toxic

(*Continued on Page* 196)



Electronics Actuates Tracer Control

By R. F. Helmkamp
Technical Sales Division
Air Reduction Sales Co., New York

PHOTOELECTRIC tubes have been applied successfully to solve many industrial problems—where greater accuracy or a more fully automatic control than that provided by mechanical systems is demanded. A new type of tracing device, popularly known as the "Electronic Bloodhound", which extends the advantages of electronic control to the gas flame cutting field recently has been introduced for use with pantograph type oxyacetylene cutting machines. This method of control radically simplifies cutting operations, while at the same time assuring greater tracing accuracy—especially when complex cuts are required.

With this device, flame cutting has been made a fully automatic process,

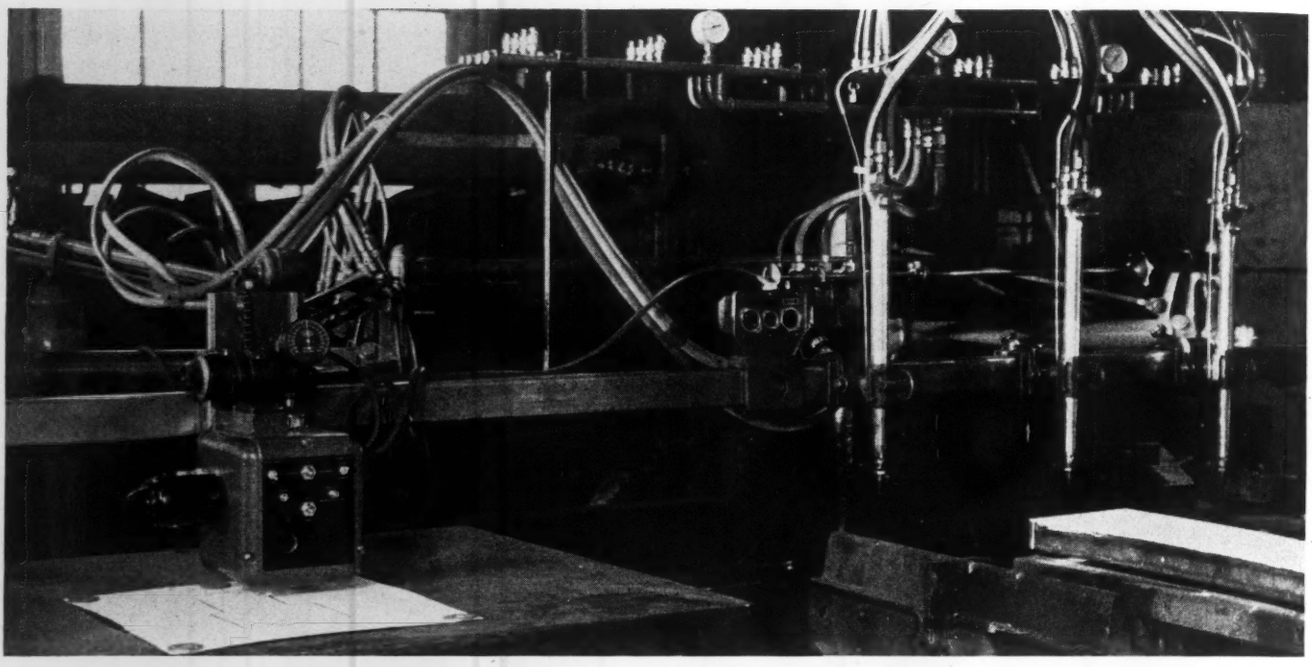


Fig. 1—Above—Electronic tracing equipment installed on Oxygraph cutting machine

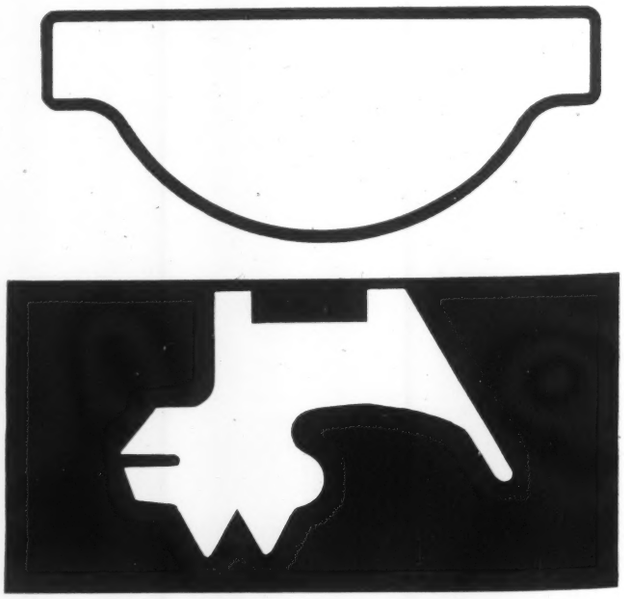
expanding the present application of torch cutting machines in industry. Expensive metal and wood templates and all other mechanical or manual auxiliary guiding devices have been completely eliminated as the new device traces from easily prepared outline drawings or silhouettes with uniform accuracy whether the order calls for one piece or a thousand pieces. There are no limitations to the variety of designs which may be cut as the electronically-controlled tracing head faithfully follows the most complex angles and curves accurately. This new electronic tracing device is illustrated in *Fig.* 1 on an Oxygraph cutting machine.

A product of joint research conducted by Air Reduction and General Electric, electronic control for gas cutting machines has been developed in an effort to adapt all phases of steel shape cutting to postwar production requirements, and to assure better quality and consistency of cut while materially decreasing the overall cost of production cutting operations.

Greater Accuracy Achieved

Until now, it has been conceded generally that the most automatic and accurate method of tracing for machine cutting has been accomplished with a magnetic tracing device. As anyone familiar with magnetic tracing knows, many steps are involved in the preparation of the steel templates which guide the magnetic spindle. Such templates must be carefully machined for accurate reproduction and, when complex cuts are required, the more intricate sections usually require subsequent machining. Accuracy with such templates is limited by the ability of the tracing device to follow the template contour, complex shapes thus being impossible to produce without the use of elaborate jigs and some additional machining of the cut piece. This disadvantage is particularly evident when inside and outside corners are encountered.

Fig. 2—Below—Typical silhouettes and simple outline drawings which replace conventional templates with electronic tracing equipment



Low cost template preparation cannot be stressed too strongly as one of the most important economic factors in shape cutting operations. Drawings or silhouettes which are used as templates for electronic tracing equipment are easily prepared by a variety of methods from paper, cardboard or plastic material. Black ink or heavy pencial lines on white paper, silhouettes inked on a white background, or mounting a design cut from black paper on a white background are some methods which have

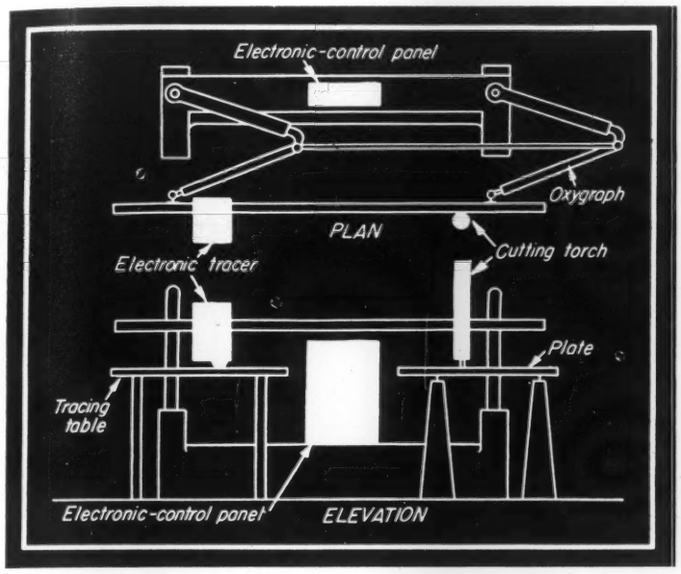


Fig. 3—Above—Plan and elevation showing arrangement of electronic tracing head and control box

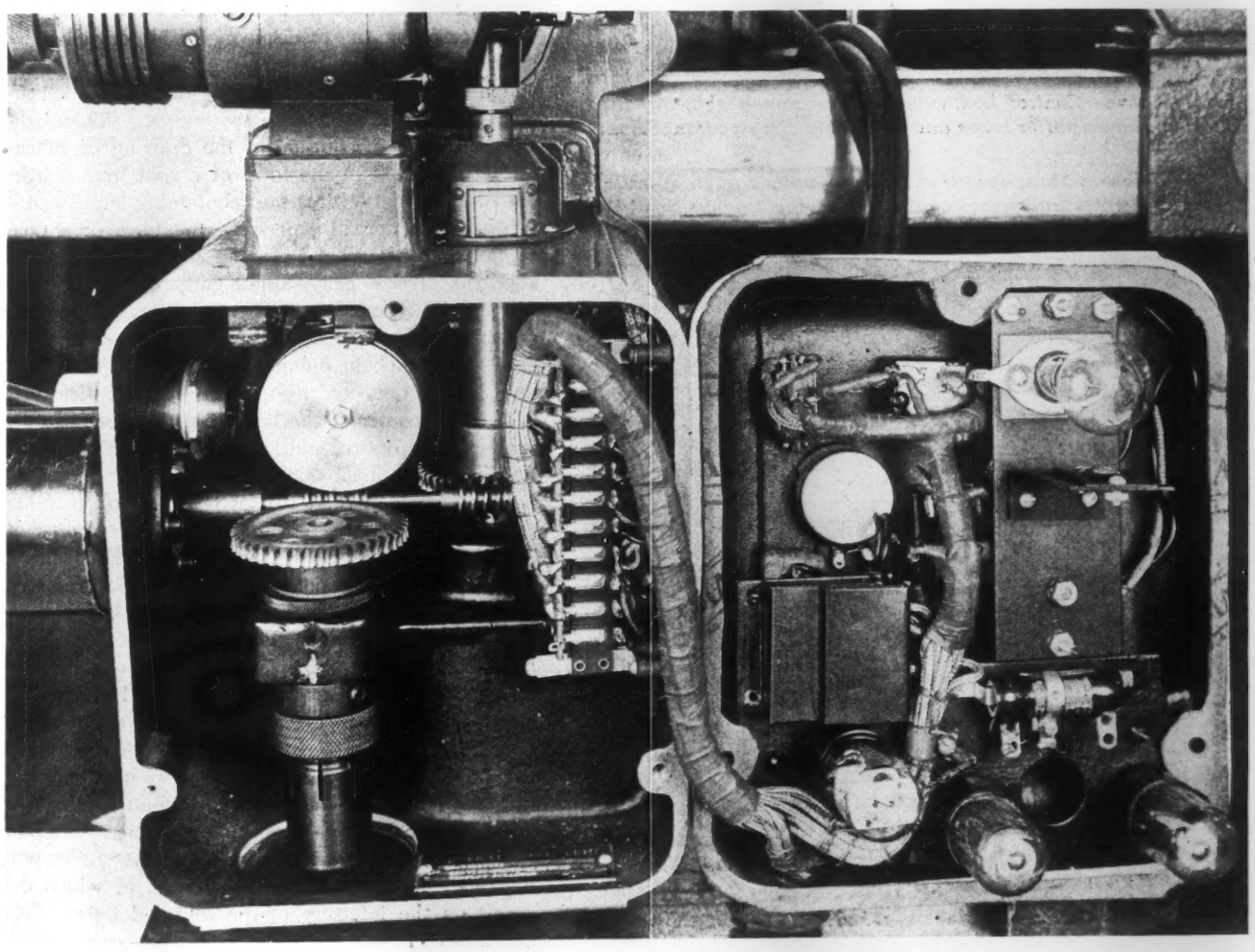
Fig. 4—Below—Internal view of tracing head and cover showing phototubes, amplifier tube, light bulb, optical unit and steering motor drive. Direction indicator is located at top of head

produced excellent results. Although a black and white combination is recommended, any color combination may be used which provides sufficient light intensity contrast. Examples of these templates are illustrated in *Fig.* 2.

A new field of application has been opened in machine production cutting through the "chain" method of reproduction made possible with an interconnected type of template. In this method of cutting, a series of identical designs are drawn and connected to each other with a heavy line. The electronic head follows these lines after each individual cut has been completed, making possible a number of duplicate or related cuts in but one single operation.

This electronically controlled tracing equipment consists of two units—the tracing head and a control box. The tracing head is a self-contained unit replacing a manual or magnetic device and is attached in the same manner to the bar on standard pantograph type machines. No modifications or alterations to the machine are necessary. A plan and elevation view of the tracing head and control box arrangement is illustrated by the schematic diagram in *Fig.* 3.

Nearly everyone acquainted with machine cutting



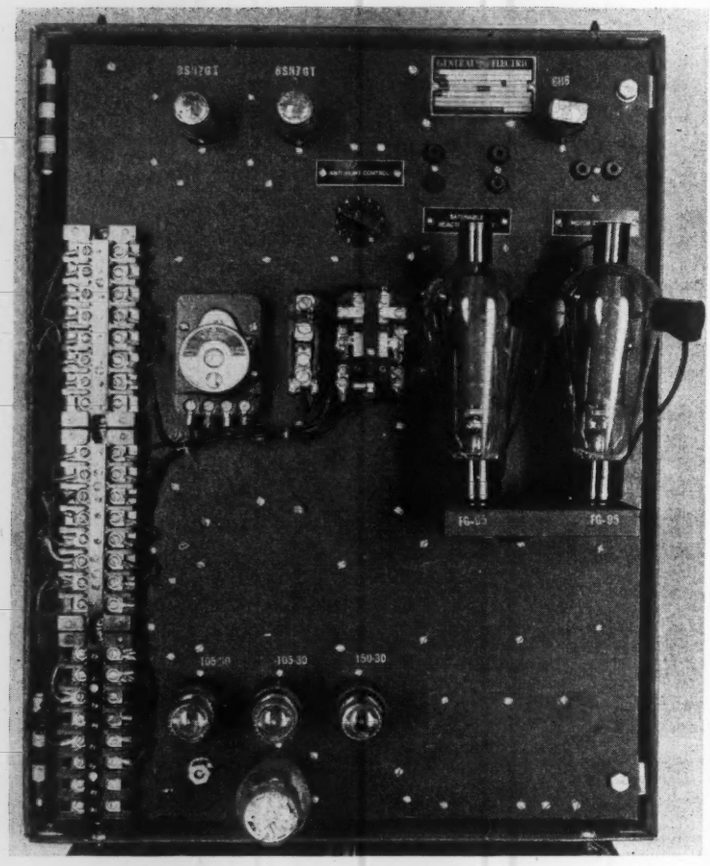
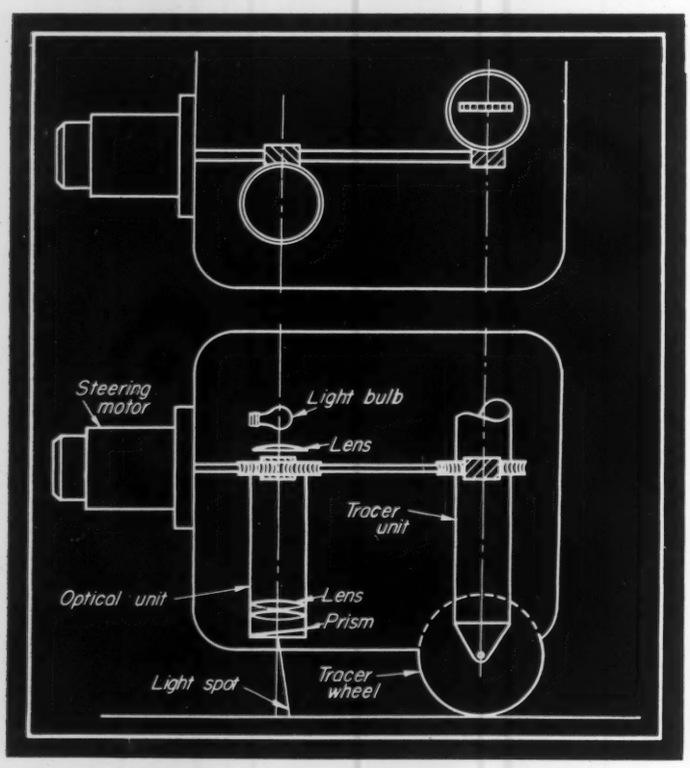


Fig. 5—Above—Control box with cover removed showing the thyratron and amplifier tubes and electronic circuit arrangement

Fig. 6—Below—Arrangement of optical unit, tracer spindle, steering motor and worm gear drive in the tracing head



is familiar with the conventional type of manual tracing device. This type of tracing mechanism moves the arms of a pantograph by the tractive force exerted between a driving wheel and the surface of the table with which it makes contact. The driving wheel is rotated by means of shafts and gears motivated by the tracer motor positioned at the top of the unit. The direction of travel is affected by rotation of the driving wheel about a vertical axis. Such a tracing device is guided manually over a drawing or template by the operator. In shape cutting, the operator is called on to steer or rotate the tracer an exact amount at the proper instant.

Torch Control Fully Electric

Primary interest in electronic control of the oxy-acetylene cutting process lies in the method by which the tracing head controls torch movement. Internal views of the tracing head and control box illustrated in *Figs.* 4 and 5 show the electronic tracing control equipment. Primarily, this method of torch control is fully electric—all parts such as motors, switches, electronic circuit, and optical system are completely enclosed as a precaution against oxide, slag, dirt, rough handling and other conditions inherent in flame cutting operations. This protection assures trouble-free operation.

Operation of the steering motor is controlled by light emitted from the base of the tracing head which is reflected back from the drawing or silhouette and picked up by phototubes. This light which follows the outline of the drawing or silhouette is projected in the form of a spot from a light bulb through an optical unit containing lenses and a prism. The optical unit is in the form of a tube supported by a vertical bearing and is free to rotate about its vertical axis. Light gathered by the optical system is concentrated so that, when focused on the surface of the template, a light spot about 3/32 of an inch in diameter is formed. This small light spot is deflected by a prism in the optical unit so that the center of the light spot is offset from the center of the optical unit.

When the optical unit is rotated about its center, the small spot of light rotates on the surface of the template in a path having a 3/32-inch radius or 3/16-inch pitch circle. This freedom of movement which permits the spot of light to continually seek to position itself half on the black line and half on the white background gives the electronic tracing head its ability to follow any curve or angle. This arrangement is illustrated in *Fig.* 6. It is the intensity of this reflected light which controls the movement of the steering motor and for this reason the drawing or silhouette used in place of a template must be made in black against a white background or another color combination of sufficient contrast.

Reflected light picked up by the phototubes produces an electric signal, the strength of which depends on the intensity of the reflected light. This signal is then amplified to provide the current which

flows through the steering motor armature and causes its rotation. Thus, if the light spot is directed entirely on the black area, much of the light is absorbed and a weak signal is produced. Conversely, if the spot is directed on the white background, most of the light will be reflected back to the phototubes, producing a strong signal.

When the tracing head is following a straight line during a cutting operation, the light spot remains centered, half on the black area and half on the white background. Through the electronic circuit, the steering motor is so adjusted that when this condition exists, no rotation of the armature takes place. This is illustrated in *Fig.* 7. If more than half the spot of light should cover the black area, a resultant decrease in signal strength causes the steering motor armature to rotate both the optical system and the tracer spindle in a counterclockwise direction until equilibrium has been restored—thus again neutralizing the signal and causing the steering motor to become inoperative as shown in *Fig.* 8. In the same manner, if the light spot tends to leave the black outline and more than half center on the white background, the strong signal produced by the increased light intensity causes the steering motor to rotate the optical system and tracer spindle in a clockwise direction until equilibrium has been restored as shown in *Fig.* 9.

In operation, the optical unit is free to rotate about its center in the same manner in which the tracing device rotates. The optical unit and tracing device are connected by means of a worm gear drive so that the units rotate simultaneously an equal amount in the same direction.

Produces Smooth Curves

When a curved line is followed the light spot will transmit a constant slight or strong signal, depending on the direction of the curve, so that the tracing head follows the curve evenly and, with the aid of an antihunt device, produces a smooth cut.

Cumulative errors due to slipping of the driving wheel which are prevalent in other methods of torch control have been eliminated as the electronic tracing head constantly compares torch position directly with the drawing or template used. Also, the fact that this control provides a smooth, even corrective action as

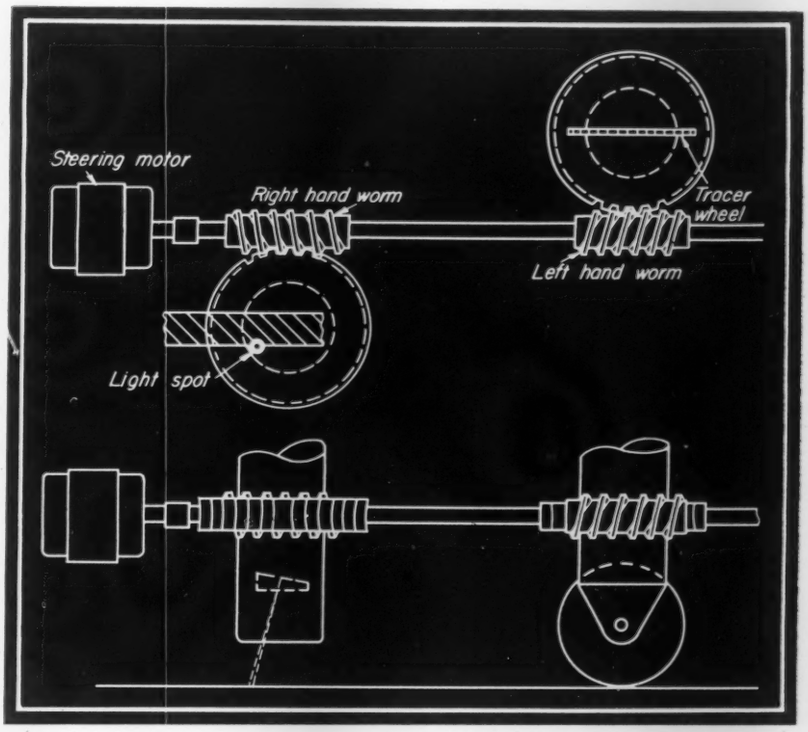
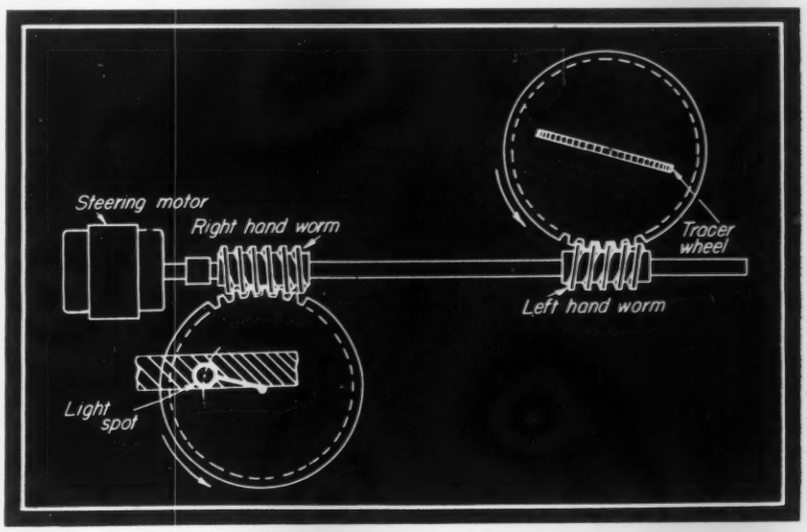


Fig. 7—Operation of the tracing head when following a straight line. Light spot is centered, half on the black outline and half on the white background. When this condition exists, no rotation of the steering motor takes place

the spot varies from its correct position instead of full on or off control, assures correction which is proportional to the amount of error.

The tracing head unit consists of the optical unit, the tracing device which includes two phototubes, an amplifier tube, light bulb, and potentiometers, a direction indicator, a switch panel, adjustment controls, and the necessary electric connections. To assure perfect electronic control under all operating conditions, the electrical and optical units are housed in dust-tight chambers. In addition, three motors are provided which control the

Fig. 8—Below—Operation of steering motor when more than half the light spot is focused on the black outline. Decreased signal strength causes the steering motor armature to rotate both the optical system and the tracer spindle counterclockwise until light equilibrium has been restored



tracing head movement—the steering motor, the tracer driving motor and a motor which raises or lowers the head.

A vertical track guides the tracing head when it is raised or lowered and sealed ball bearings are used throughout. Finger-tip control assures responsive operation and the unit may be raised above the table to any desired level by merely lifting the handle of a momentary contact switch. The unit may be lowered to rest on the tracing table by means of the same switch, the movement being controlled by a motor driven sprocket and chain. At rest on the surface of the table the head is supported by the tracing drive wheel and resultant slack in the chain permits sufficient freedom to allow float in a vertical plane.

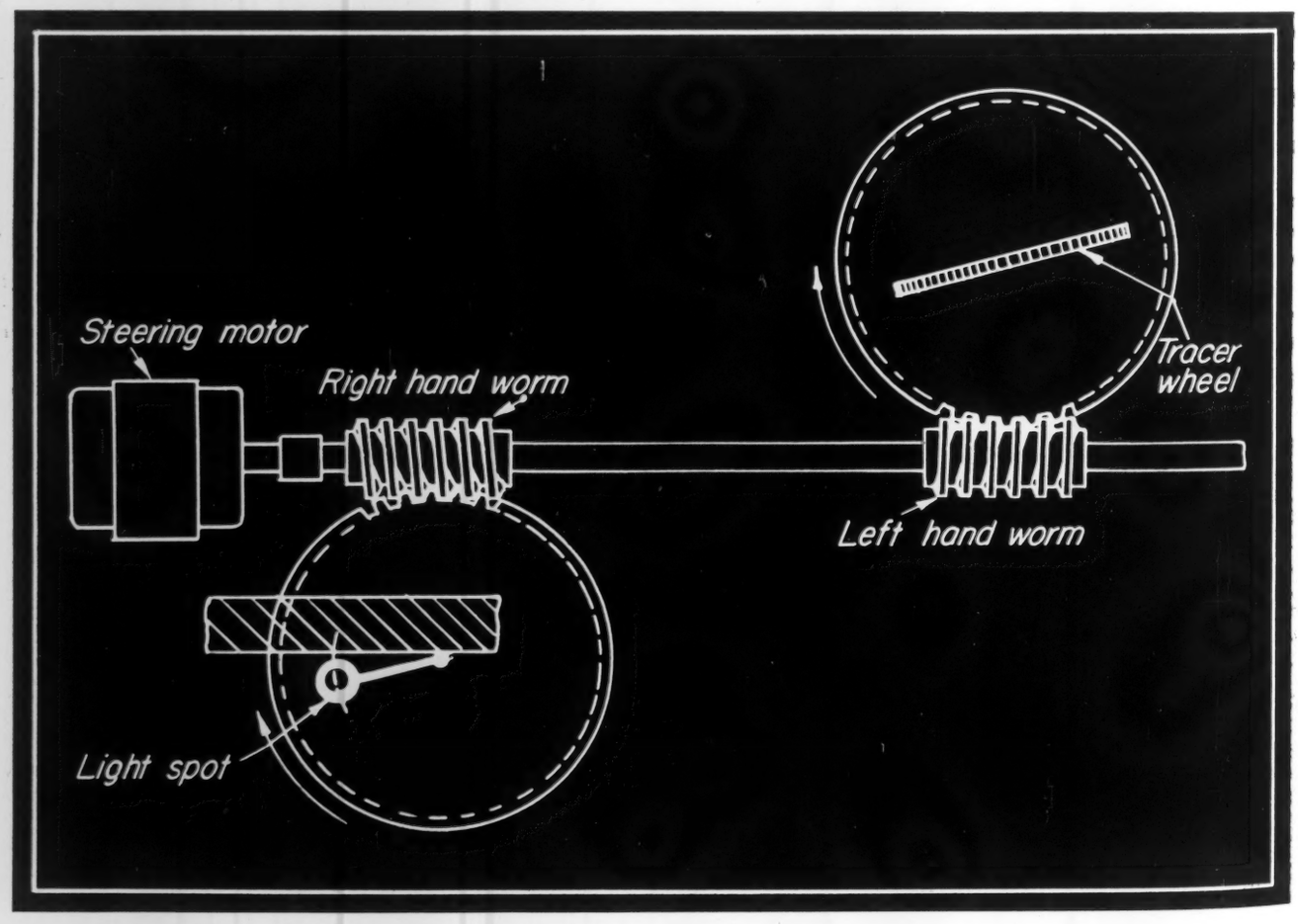
A governor-controlled motor operates the tracing drive wheel assuring a range of speeds sufficiently wide to enable cutting all thicknesses of material from light sheet to heavy plate. Cutting speed may be preset or changed during the operation, and absolute control is assured through a tachometer which indicates cutting speed. An observation window is provided in the front face of the tracer head to enable the operator to observe the light spot.

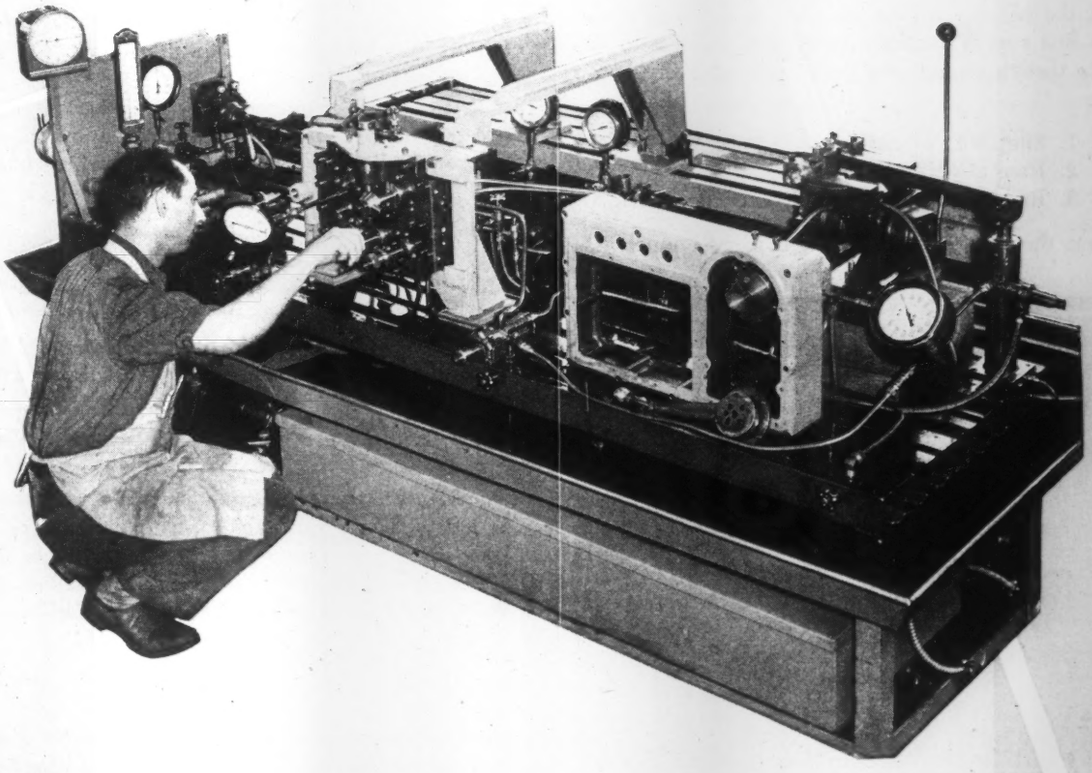
Fig. 9—Below—Operation of steering motor when more than half the light spot is on the white background. Increased signal strength causes the steering motor armature to rotate both the optical system and tracer spindle clockwise until equilibrium has been restored

This facilitates lining up the spot with the drawing and permits the operator to view the light spot and portion of the template being traversed.

Control switches are mounted on the front face of the tracer head as shown in *Fig.* 1 and the lead illustration. A single-pole switch controls the tracing device motor. The momentary contact switch raises or lowers the scanning head to permit rapid manual movement of the unit over the tracer table. Movement of the tracing device wheel may be preset through a momentary contact jog switch. Thus, it is possible by means of this switch to position the tracing drive wheel at any desired angle. Manual and automatic switches have been provided for switching from electronic control to manual operation or vice versa. Two potentiometer knobs are provided for balance and sensitivity in the operation of the steering motor.

Accuracy of tracing with electronic equipment is within a few thousandths of an inch and depends of course upon the accuracy of the drawing. During a test, the tracer head automatically traced over a drawing of a rectangular design for several hours continuously, using a scriber in place of a torch to scratch a line on a chalked plate, and no appreciable change in width of the scribed line could be observed. No difference in measurement between the drawing and the scribed line could be detected and extremely difficult and intricate corners presented no tracing problems.





Machine Hydraulics

By Albert H. Dall
Assistant Research Director
The Cincinnati Milling Machine Co.

Part I—Throttle Circuits

ONE of the chief uses of hydraulics is for variable-speed power transmission, infinitely variable speed ranges as high as 250 to 1 having been used successfully on machine tool slides and similar applications. One requirement of such transmissions is that the slide must operate smoothly at all feed rates. A further requirement is that the force generated by the hydraulic transmission be at least constant over the full range; in some cases, the designs require that the available force increase as the feed rate decreases.

Various systems for obtaining infinitely variable rates in hydraulic transmissions have been used. The circuits for these systems can be classified into two

main types, which are as follows:

1. Throttle circuits
2. Variable delivery pump circuits.

Each of these types has advantages which must be weighed against their disadvantages. The throttle type circuit has the advantage over the variable-delivery circuit in that its first cost is usually much lower. Other advantages of the throttle circuit over the variable-delivery pump circuit are:

1. Simplicity of design
2. Ease of control
3. Ruggedness of component parts.

However, the throttle type circuit is usually much less efficient at all feed rates other than maximum. The variable-delivery pump circuits have a further advantage over the ordinary throttle circuit in that they will hold the feed rates constant irrespective of load.

It is one of the purposes of this article to show that the latter disadvantage of the throttle circuit can be entirely overcome by circuit design and further that the disadvantage of inefficiency of the throttle circuit can be circumvented partially.

Performance characteristics of the various throttle control circuits are quite easily analyzed by the use of the fundamental equation of the throttle, which is

$$P_d = QR \quad \ldots\ldots (1)$$

where P_d = Pressure drop across the throttle
Q = Flow through the throttle
R = Resistance of the throttle.

This equation is analogous to the electrical equation

$$E = IR \quad \ldots\ldots (2)$$

While it is true that Equation 1 is simply the Poisseuile equation and is applicable only to laminar or streamline flow, it has been found to be of great value in the analysis of the various throttle circuits for purposes of comparison. The general equation of the throttle should be

$$P_d = Q^n R \quad \ldots\ldots (3)$$

where n has some value between 1 and 2. For purposes of simplicity the performance curves are based on $n = 1$. Since the term R in the foregoing equations contains the viscosity term for the fluid, it is necessary to make the further assumption that the temperature of the fluid is constant.

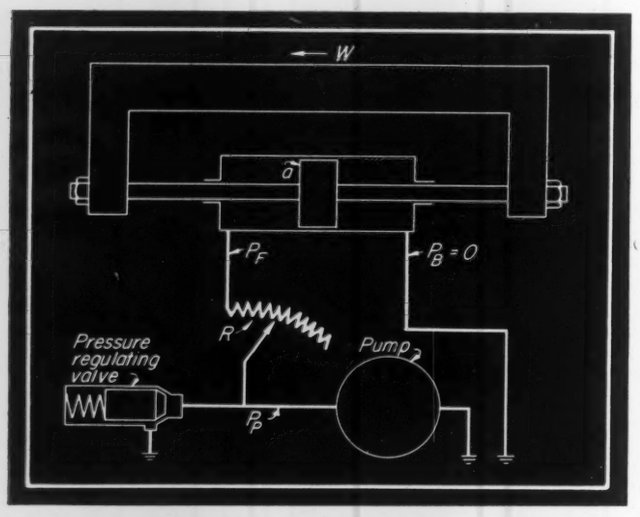
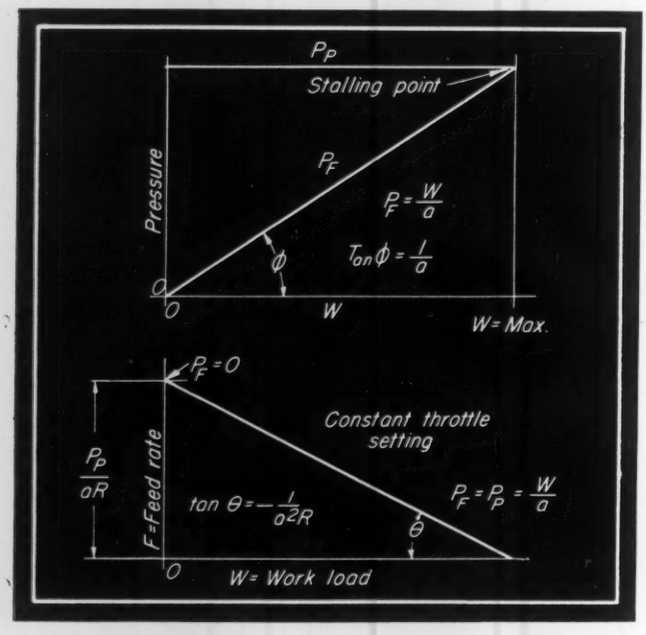


Fig. 1—Above—Simple throttle circuit with throttle in forward pressure line. Throttle resistance, denoted by R, is analogous to that of a rheostat

Fig. 2—Below—How pressure and feed rate vary with work load for throttle circuit shown in Fig. 1



***THIS ARTICLE** inaugurates a series which will cover various important aspects of the design and application of hydraulic circuits for machine drives and controls. The articles will include information not previously published, although many of the special circuits have been disclosed in patent papers. Subsequent parts of the series will appear at frequent intervals during the year*

THROTTLE CIRCUITS: In any throttle circuit, a shunt must be provided in order to by-pass some of the fluid from the pump to the tank. The remainder of the fluid causes motion in the hydraulic motor at some fraction of the maximum rate. This shunt is a valve which also acts as a pressure regulator or compensating valve. The shunted oil represents a loss in energy which accounts for the inefficiency of throttle circuits. Horsepower output of a pump is

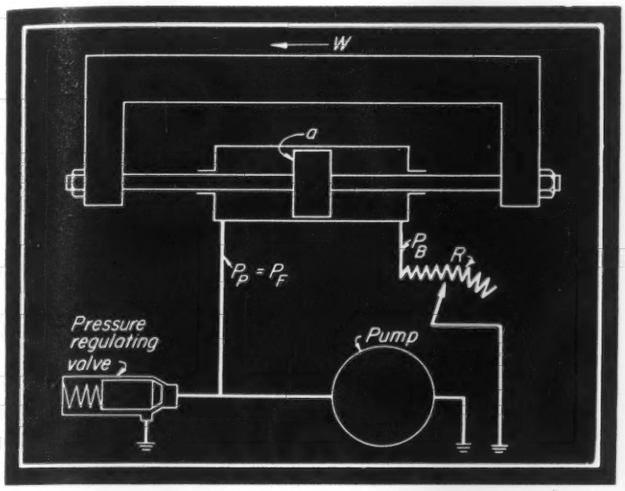
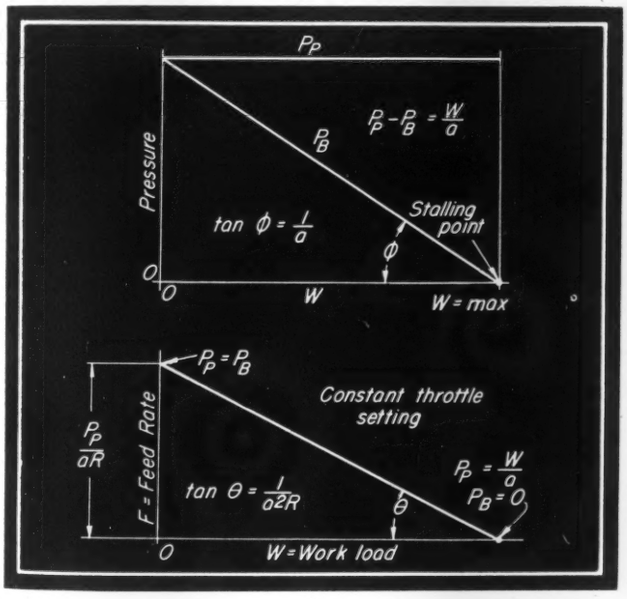


Fig. 3—Above—Circuit with throttle in back pressure line insures some control regardless of load direction

Fig. 4—Below—Performance characteristics of simple circuit with throttle in back pressure line (Fig. 3)



$$\frac{P_p Q}{396000} = HP \qquad (4)$$

where P_p = Pump pressure, psi
Q = Quantity delivered, cu in. per min.

It is obvious therefore that if 2/3 of the fluid is shunted to the tank at the pump, the hydraulic efficiency under the conditions of 1/3 the maximum feed rate cannot be more than 33 per cent. The energy lost is further augmented by the loss through the throttle.

The actual hydraulic efficiency of any circuit is the output work at the hydraulic motor per unit of time divided by the input work per unit of time at the pump. Thus

$$\text{Efficiency} = \frac{F W}{P_p Q_p}$$

where F = Feed rate, in. per min
W = Load, lb
P_p = Pump pressure, psi
Q_p = Quantity delivered by pump, cu in. per min.

Delivery of the pump, Q_p, is constant on throttle circuits and is determined by the maximum desired feed rate. The pump pressure, P_p, is determined by the maximum load which the system will be called upon to support. If the pump pressure can be made to vary with the load, W, it can be seen that the efficiency of the system can be materially increased at loads below the maximum. It will be shown that this result can be obtained with the proper compensating valves.

Simple Throttle Circuit: In *Figs.* 1 and 3 are

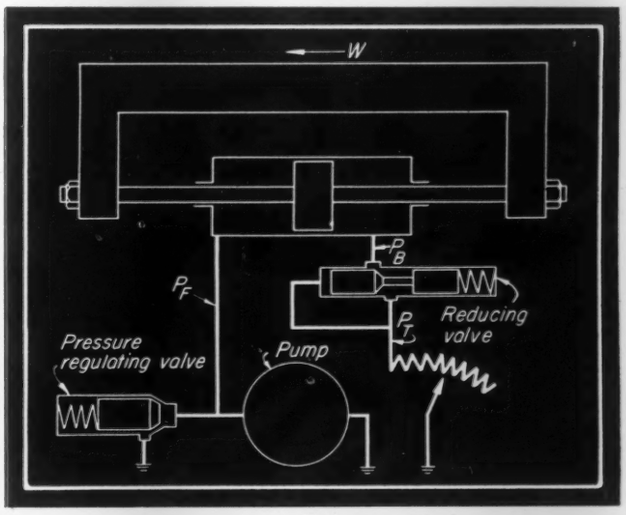
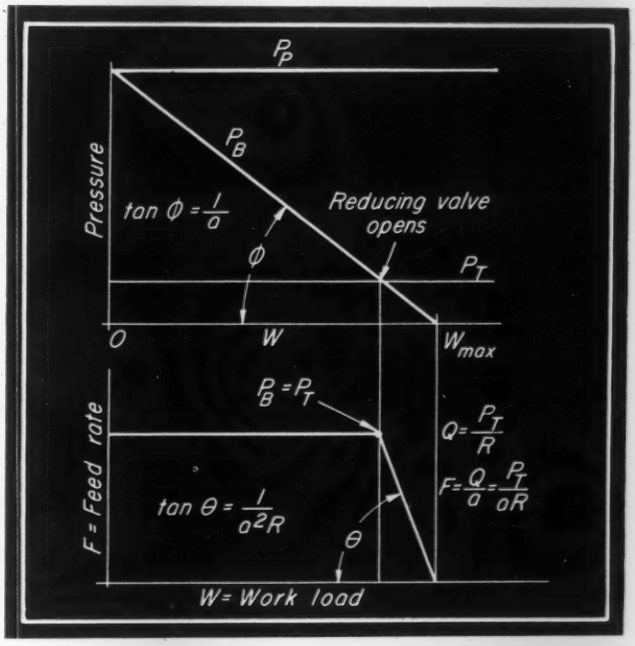


Fig. 5—Above—Circuit with constant pressure across throttle, provided by reducing valve in series with throttle

Fig. 6—Below—Performance curves for circuit of Fig. 5 indicate virtual elimination of feed rate variations



shown the simplest types of throttle circuits. In *Fig.* 1 the throttle is in the forward pressure line, while in *Fig.* 3 the throttle is in the back pressure line. Inasmuch as the pressure drop across the throttle is $P_p - P_f$, Equation 1 may be written

$$P_p - P_f = QR \quad \ldots\ldots (5)$$

where a is the effective area of the motor. Since $W = P_f a$, the feed rate is

$$F = \frac{Q}{a} = \frac{P_p - P_f}{aR} = \frac{P_p}{aR} - \frac{W}{a^2 R} \quad \ldots\ldots (6)$$

The curves in *Figs.* 2 and 4 show that the performance characteristics of the two circuits are virtually identical. Under the same pressure conditions both circuits will carry the same maximum load. The rate of change of feed rate with load is identical for constant throttle setting.

A disadvantage of having the throttle in the forward pressure line, *Fig.* 1, is the absence of back pressure in the actuating cylinder. Thus a negative load, W, is entirely unopposed and the slide tends to run away. Placing the throttle in the back pressure line, *Fig.* 3, imposes the necessary back pressure and insures a measure of control of the slide regardless of load direction.

When reversing operations are used it is advisable to use a foot valve on either circuit in order to keep the system full at all times. The presence of entrapped air anywhere in the system will usually detract from the smoothness of operation. The foot valve acts as a check valve in the return line from the system. Of course, this will result in a slight increase in the pressure level of the system, depending on the pressure drop through the valve.

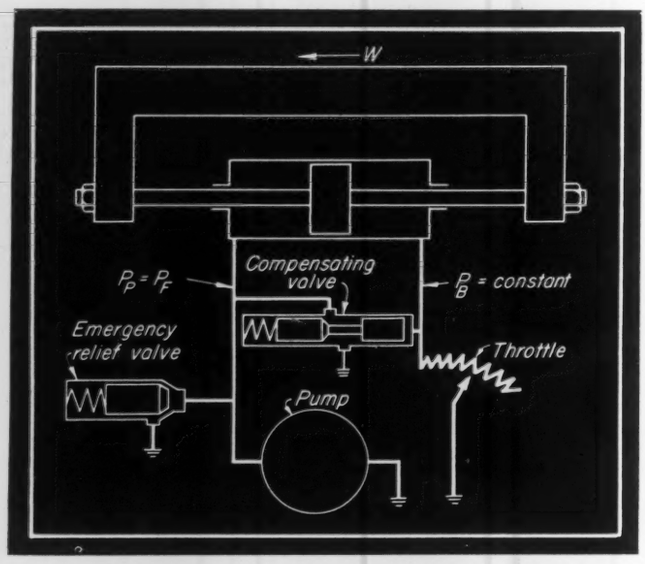
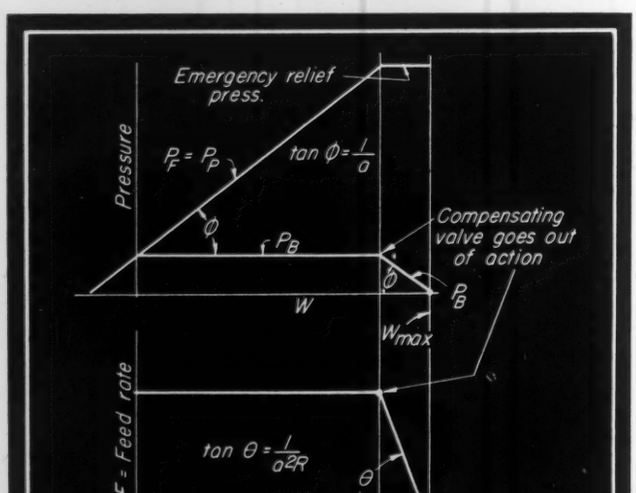


Fig. 7—Above—Throttle circuit with load compensating valve controlled by back pressure

Fig. 8—Below—Characteristics of circuit shown in Fig. 7. Pump pressure assumes any value required by load



Compensating Valve Gives Constant Feed Rate

THROTTLE CIRCUIT WITH FEED RATE COMPENSATION: In the circuits of *Figs.* 1 and 3 the variation in feed rate with load at constant throttle setting was caused by variation in the pressure drop across the throttle. In *Fig.* 5 is shown a circuit which almost entirely eliminates variations in feed rate with load. The reducing valve in the back pressure line insures a constant pressure drop across the throttle at all loads up to the condition where the back pressure falls below the throttle pressure. The efficiency of this system, *Fig.* 6, is identical with that of the previous systems.

Value of the throttle pressure drop can be set at a relatively low value. On the systems shown in *Figs.* 1 and 3 the drop across the throttle may be a large percentage of the pump pressure at times. Because of the small throttle openings at low feed rates and the high pressure drop, clogging of the throttle is not unusual. With the system shown in *Fig.* 5 the throttle openings are larger for the same flow and thus the hazard of clogging is minimized. The self-compensating throttling by the reducing valve which is in series with the throttle valve makes this possible.

THROTTLE CIRCUIT WITH LOAD-COMPENSATED PUMP PRESSURE: It is now apparent that a constant pressure drop across the adjustable throttle is highly desirable in order to obtain a feed rate independent of the motor load. A further desirable feature from the standpoint of efficiency would be to have the pump pressure vary with the load. Thus in the efficiency formula,

$$\text{Efficiency} = \frac{F}{Q_p} \times \frac{W}{P_p} \quad \ldots\ldots (7)$$

the term W/P_p would remain constant and the efficiency would vary directly with feed rate only. In *Fig.* 7 is shown a throttle circuit designed to accomplish this purpose.

In this circuit the shunt throttle is controlled from the

back pressure, thus any tendency for the back pressure to rise will decrease the shunt resistance until the flow through the throttle is such as to give a back pressure sufficient to balance the spring. The forward pressure, which is also the pump pressure, can assume any value depending on the load. It is evident that even a slight negative work load can be supported as shown on the diagram, *Fig.* 8.

THROTTLE CIRCUIT FOR LARGE POSITIVE AND NEGATIVE WORK LOADS: *Fig.* 9 shows a circuit which employs the differential relief valve. This valve controls the forward or pump pressure by means of the forward and back pressures on the motor. The spring force on the valve is supported by both these pressures which act in the same direction. Thus the sum of the forward and back pressures must remain constant if the two areas on which they act in the valve are equal.

In order to maintain equilibrium axially, a rise in forward pressure must be accompanied by a drop in back pressure, or vice versa. When the load is in the direction of feed (negative load) the back pressure oil column compresses and the forward pressure column expands. If the rate of compression or expansion are equal, the differential valve will not move. If these rates are not equal, the valve will change position to adjust to the new pressure conditions.

Pressure changes with respect to load are shown in *Fig.* 10. Under the influence of negative loads, back pressure may rise to large values. The load-pressure relation remains the same as that for the other systems. However, a second relation between these pressures is determined by the differential relief valve. Thus,

$$P_f - P_b = \frac{W}{a} \quad \ldots\ldots (8)$$

$$P_f + P_b = \frac{S}{a_1} \quad \ldots\ldots (9)$$

where a is the effective area of the motor and a_1 is the area on which forward and back pressures act on the valve, assuming they are equal.

Adding Equations 8 and 9,

$$Pf = \frac{W}{2a} + \frac{S}{2a_1} \quad \ldots\ldots (10)$$

The slope of the forward pressure curve with respect to load would therefore be $1/2a$ and the slope of the back pressure curve would be $-1/2a$. It can be seen that the rate of change of pressure with respect to load is therefore one-half of that obtained on the previous circuits. Thus this circuit would have twice the hydraulic rigidity of the other circuits.

The reducing valve in the back pressure line serves two purposes. It serves as a variable throttle to vary the back pressure and at the same time keeps the pressure drop across the adjustable throttle at a constant value. Since the pressure drop across throttle is held constant, the feed rate will stay constant and independent of load as shown by the curves on the chart, *Fig.* 10.

If the areas on which the forward and back pressures act on the valve have a ratio other than 1 : 1, the slopes of the curves of pressures versus load are changed to other values than $1/2a$. If the slope of the P_f curve is increased, the slope P_b will decrease.

DISTRIBUTIONAL VALVES: The circuits shown in *Figs.* 1, 3, 5, 7 and 9 are simplified versions which indicate the methods of pressure and rate control. In every case the

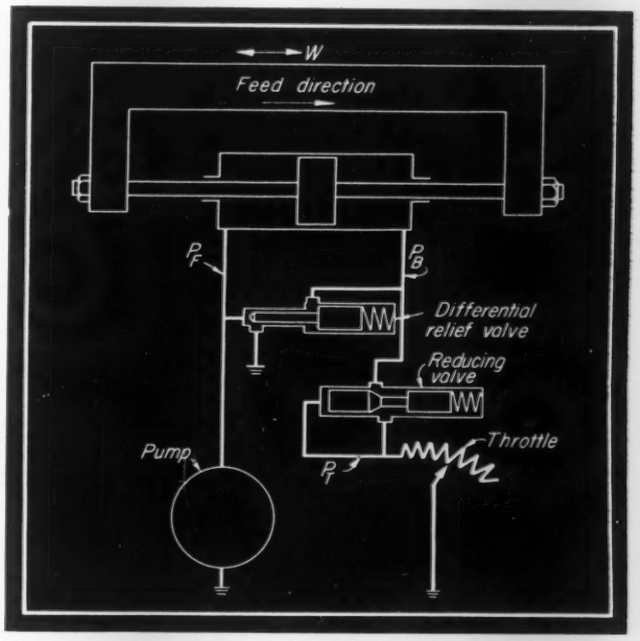
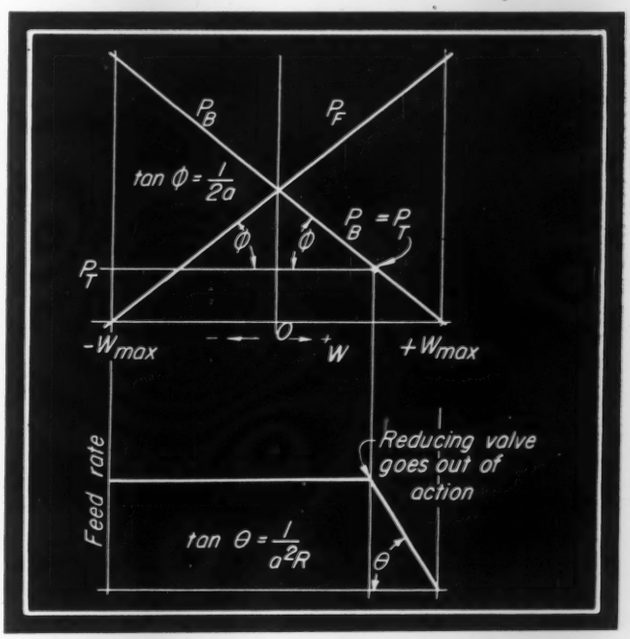


Fig. 9—Above—Throttle circuit for large positive and negative work loads, using differential relief valve controlled by forward and back pressures

Fig. 10—Below—Curves for circuit in Fig. 9 show both forward and back pressures varying with load while feed rate remains virtually constant



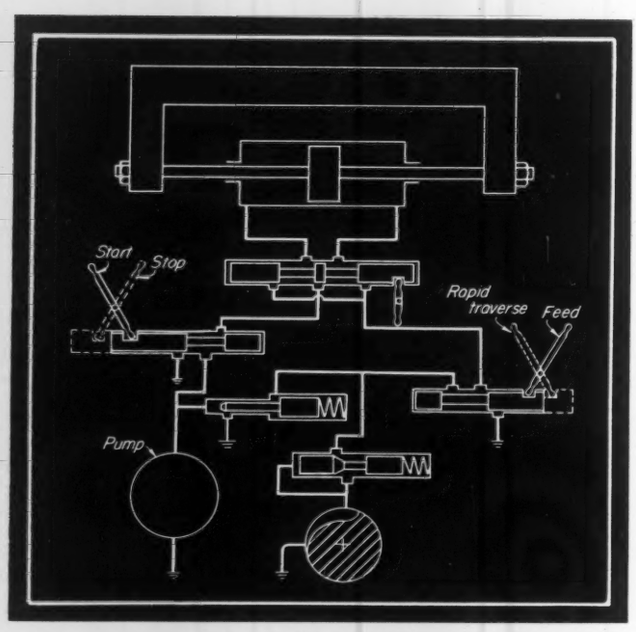


Fig. 11—Circuit shown in Fig. 9 with the addition of three valves necessary for practical operation of the machine

circuits must be supplemented by other control valves of the distributional type. These valves should have no influence on the rate or pressure characteristics of the system. Therefore the lines which carry the oil from one part of the system to another should be designed with a minimum pressure drop.

In *Fig.* 11 is shown the circuit of *Fig.* 9 with a few simple flow distribution valves. To obtain reversal of the motor, a reversing valve is inserted in the motor lines. The start-stop valve stops the flow to the motor and short circuits the pump. Another valve is inserted in the motor return line to by-pass the throttles and thus full traverse rate can be realized without changing the throttle setting.

In subsequent articles other types of circuits will be discussed, including balanced circuits and variable-delivery circuits.

Controlling Flight by Pushbutton

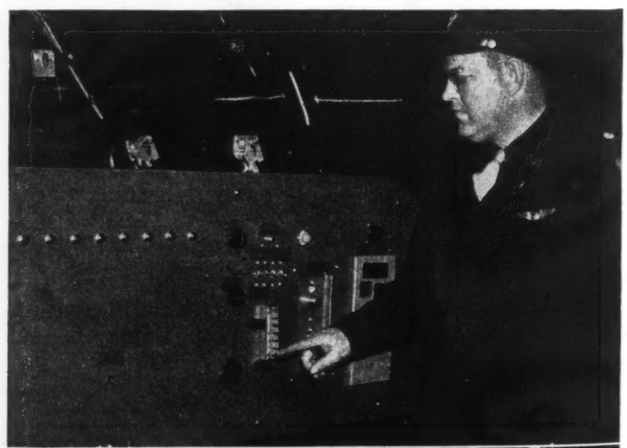
THE long dreamed-about "fully automatic" flight—virtually as simple as pushbutton tuning of a radio—has been made possible by the development, by Air Technical Service Command designers and engineers, of a mechanical brain called the Automatic Flight Controller.

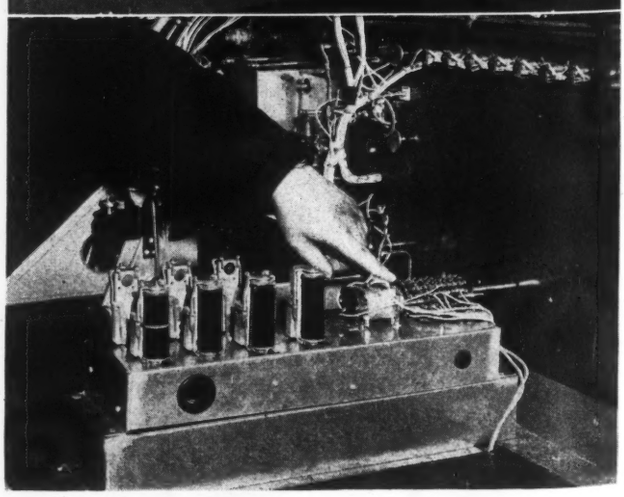
Nerve center of the controller is the master sequence selector, shown in the lower photograph at right, to which are fed the variable factors such as direction, distance and altitude—much as numbers are fed to a calculating machine. The master sequence selector then delivers impulses motivating in proper sequence the airplane controls.

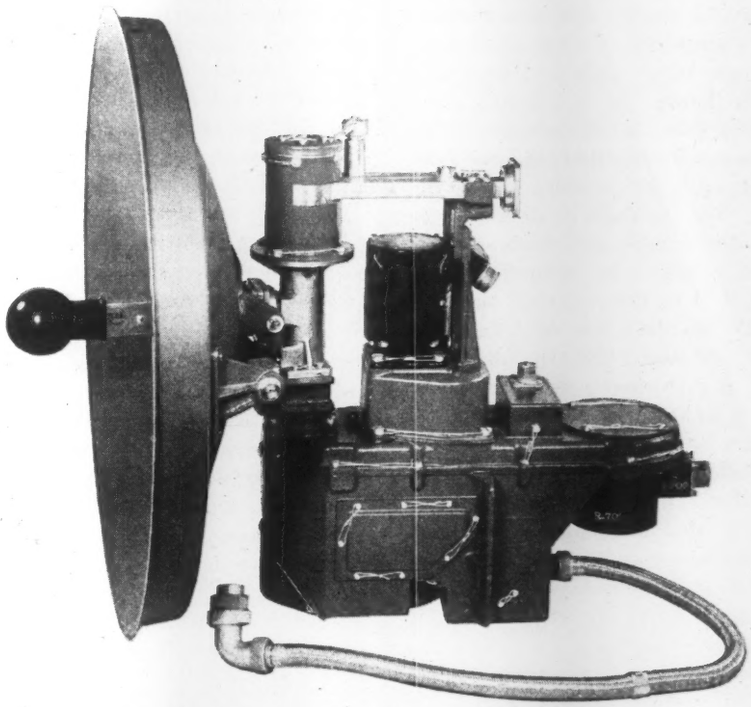
Preparation for fully automatic flight consists simply of placing the plane in position on the selected runway heading, with brakes locked and engines idle. At this stage the only manual operation is performed—a push of the button which activates the Automatic Flight Controller. Take-off procedure is initiated by automatic move up of throttle, the brakes are unlocked after eight seconds, and the aircraft takes off.

At 800 feet the pressurestat operates to move back the throttle, the wheels are retracted, flaps are raised automatically, and the aircraft climbs to cruise altitude. The pressurestat again operates and the throttle is moved back for cruise speed, the magnetic heading control is cut in, the air log starts counting air miles, the aircraft begins flight in correct direction, and the automatic altitude controls are cut in. Upon approach to destination, signaled when the air log runs down, the auto-pilot homes on the selected radio compass station. Upon passing over cone of silence marker the throttle is automatically cut back, with the automatic pilot being controlled by a compass locator station at outer marker, a down signal is fed into the elevator control circuit, and the aircraft homes on outer marker and loses altitude in an inbound position.

Upon reaching an altitude of 880 feet the pressurestat initiates the automatic operations to lower landing gear and flaps, cutting back the throttle, and cutting in automatic altitude control, with the aircraft still homing on locator station. As the aircraft passes the outer beacon marker the elevator control is operated by glide path signal. Upon touching the landing strip, the throttle automatically cuts back, brakes are applied after a delay of three seconds, while ground direction is controlled by a differential braking system until the aircraft stops.







What's Behind Airborne Radar?

By Donald M. Skidmore and Charles R. Chambers
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Part II—Control of Scanners

WHILE it is true that invention of the magnetron and the Sheppard tube made possible lightweight packaged radar* as we know it today, radar is not all tubes, condensers, resistors, etc. The ultra-high frequency beam must be transmitted and directed, and this is done mechanically by a unit which is called a scanner.

Just as the uses and applications of airborne radar are varied, there are likewise many designs of scanners. Briefly, lightweight airborne radar can be

*"What's Behind Airborne Radar?", Part I, MACHINE DESIGN, Jan. 1946, pages 107-110. Official clearance for publication of the present article was postponed by Washington for security reasons.

used for searching the surface of the sea, for enemy ships or for mapping a coast-line. It can also be used for searching the air for enemy planes.

Relationship between the actual target and the picture as seen in the indicator is shown in *Fig.* 1 which illustrates the use of the search scan. It will be seen that it is necessary to have a highly directive scanner that will not dissipate the energy of the radio wave.

The position of the target in azimuth and elevation relative to the plane must be determined by a search scanner such as that pictured in the head illustration. The radio wave—"RF" energy—is transmitted through the waveguide and reflected against the parabola which directs the beam into space. The parabola or dish, as it is commonly called, swings slowly back and forth, sweeping the horizon and earth below. An azimuth potentiometer is mechanically linked to the dish and supplies accurate azimuth information to the radar set. In addition to sweeping slowly back and forth, the dish can also tilt up and down. This provision is necessary since the attitude of the plane in flight varies considerably. A tilt potentiometer relays its information to a tilt meter located in the cockpit. Both potentiometers are variable voltage devices designed for extreme accuracy.

There are many ways to obtain azimuth sweep and tilt elevation. The real problem was how to do it simply with the greatest accuracy and obtain the lightest unit possible. The cutaway view, *Fig.* 2, shows much of the mechanism of such a search scanner. Note how the azimuth motor is geared to the reduction unit which in turn oscillates a large sector gear by means of an eccentric. Directly below the sector is housed a unit called the tilt mechanism. This is nothing more than a small shunt motor linked to two worm reductions. The extent of rotation of the last shaft is controlled by two limit switches. Here again, an eccentric on this shaft moves a link up and down, its motion being transferred to the tilt shaft running up through the hollow gear meshed with the sector gear. In operation the pilot of the plane throws the tilt switch located on the radar control box, and the switch energizes the tilt motor, thereby moving the parabola up or down the desired amount. By dynamically braking the tilt motor, it is possible to eliminate overtravel.

How Design Was Refined

The first experimental models looked nothing like the one described. Not until the first units were in service were the weak points of the design determined. For instance, in the early part of the game it was believed that the tilt mechanism should be so designed as to produce three separate stages of elevation. This proved to be inadequate as it took too long to go from the high to the low or from the low to the middle. The target disappeared from the screen because the elevation angle was not sufficient and the speed of travel was too slow. The tilt mechanism was immediately redesigned during production of the scanners, and the next unit supplied five points of tilt. This proved satisfactory from the standpoint of maintaining a wide angle, but the five point design was still not adequate. The manually operated tilt proved to be satisfactory as the pilot could position his parabola in place between the high and low limits. If it had not been for the co-operation between the operating personnel and the personnel on the job at the various plants making radar units, problems of this nature could not have been solved, as they were, in a matter of days.

As was mentioned previously, the scanner must transmit RF energy without appreciable loss. This on the surface seemed fairly simple. In reality it became one of the major engineering problems. The waveguide proved to be the most efficient method for transmitting the RF energy. A rotating joint had to be designed as it was impractical to swing the whole scanner back and forth.

It soon became apparent that the fabrication

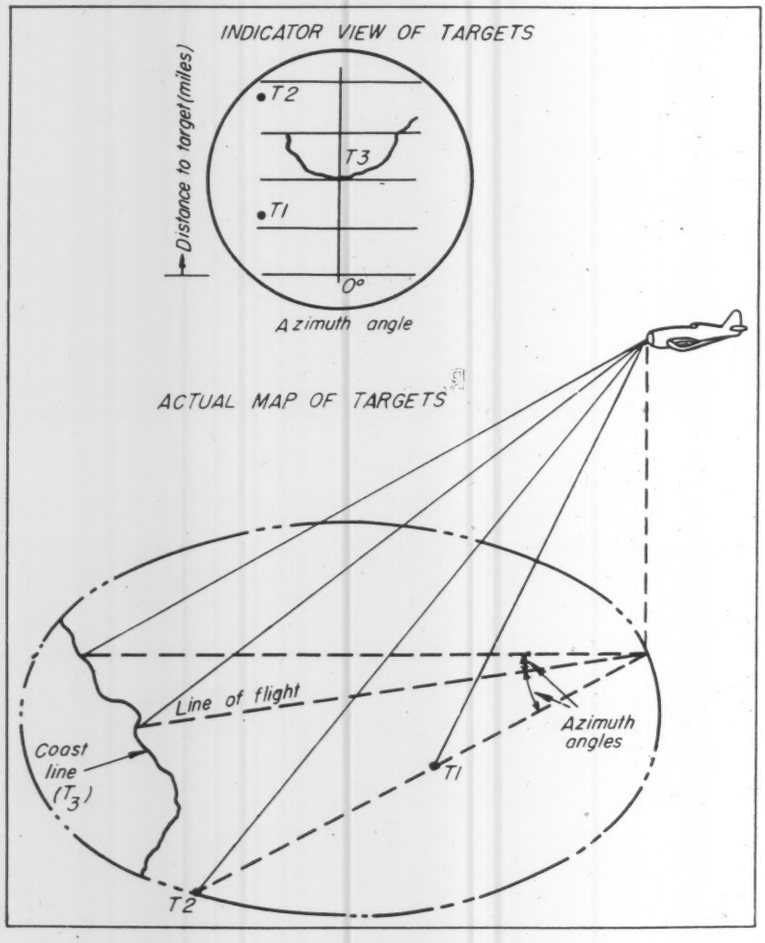


Fig. 1—Left—Diagram shows relationship between actual target (bottom) and the picture as seen on the plane's indicator (top)

of waveguide must be carried out with extreme care. Obstructions inside the guide caused reflected waves to be set up, which in turn reduced the power output.

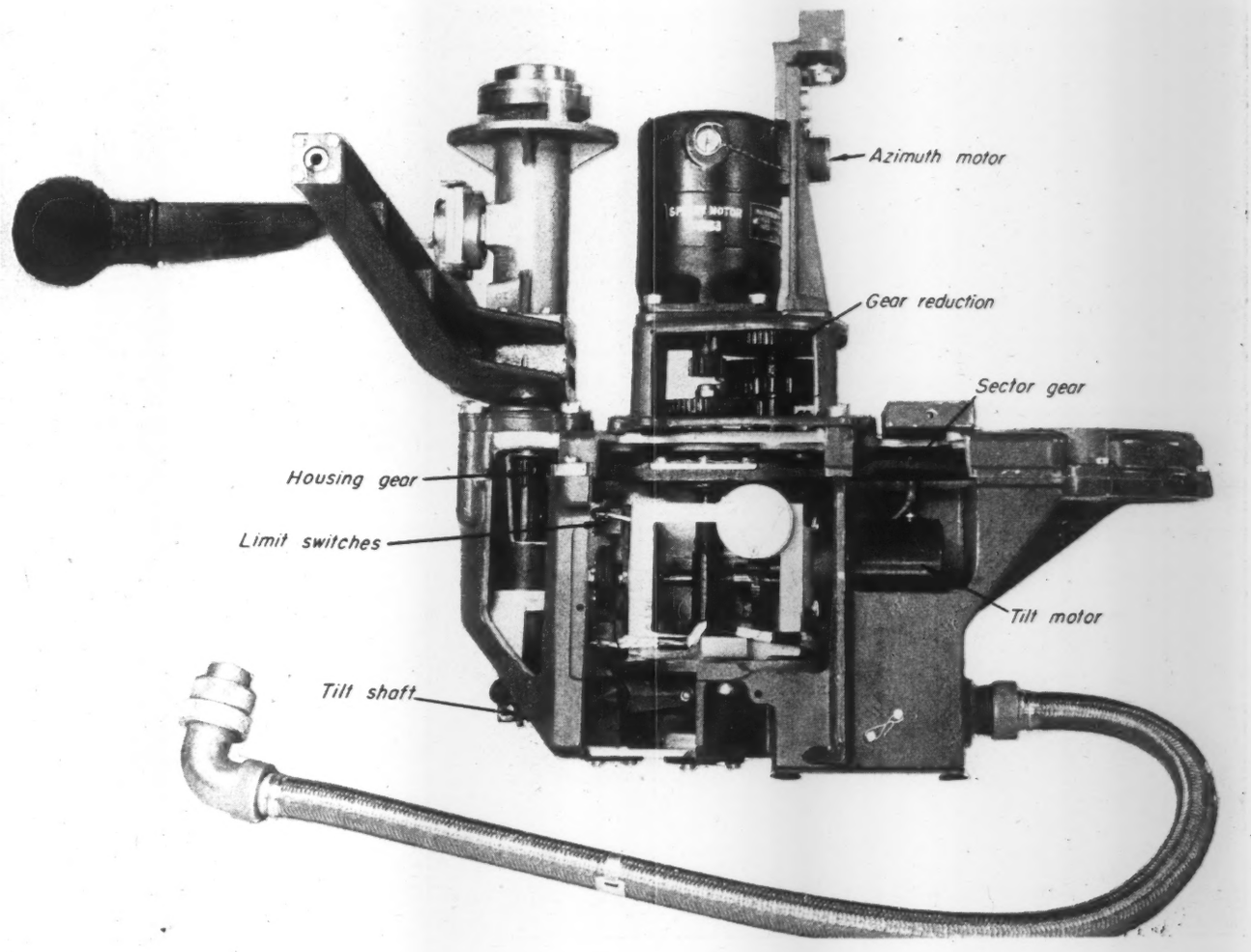
From an electrical standpoint, the design of rotating joints, waveguide chokes, and resonant cavities proved to be more or less of a hit and miss proposition as not enough was known about the characteristics of these high frequency waves. The radiation laboratory at the Massachusetts Institute of Technology and various other industrial organizations combined their efforts in an extensive program to determine the basic theories used for the design of RF transmission.

At the start, the research engineer would make up a model that he felt should work. He would test it, change it, and test it again until he finally had good transmission qualities. From a mechanical standpoint the fabrication of waveguide, which we commonly call plumbing, became quite a problem as we were always receiving new and better designs from the research men. As a result, tooling for this equipment was always in a state of flux. It was found early in the game that the waveguide would break down at high altitudes due to corona, commonly called arc-over. This was caused by the atmosphere decreasing the dielectric between the positive and negative sides of the waveguide. As a result pressurization requirements became mandatory. This presented more mechanical problems as the rotating joints had to be sealed from leakage. Pressurization also aided in that it prevented moisture, dust, and dirt from collecting inside the waveguide.

In solving these problems it was found that properly designed fixtures for brazing the units together, plus accurate machining after brazing, contributed much toward maintaining the close dimensions required. By silver plating and palladium plating over the silver, the plumbing would stand up under 200-hour salt spray tests. Use of small rotary or reciprocating air pumps, which fed clean, dry air to the plumbing, eliminated arc-over and increased the efficiency of transmission. By designing rotary rubber or optical flat steel air seals, leakage of air through the rotating joints was eliminated without appreciably increasing the torque requirements of the azimuth motor.

Lost motion between the parabola position and azimuth potentiometer indication presented another problem. Before the equipment saw service it was rather difficult to determine what tolerance in azimuth accuracy was permissible. Sound judgment had to be used because the

Fig. 2—Cutaway view of a search scanner showing some of the key components and how unit is constructed



degree of accuracy built into the equipment was directly reflected in its weight. As a result, various designs were worked out, tried in the engineering laboratory and flight tested. These tests showed that accuracy of ½-degree or less was required to make the radar effective.

Various devices were used in the mechanical gearing to eliminate backlash. A split gear was used on the azimuth potentiometer shaft, a double eccentric was used at the fulcrum point of the sector gear, and adjustable slides were used at the eccentric which oscillated the sector gear. Line-boring of the main castings also eliminated misalignment problems. These various devices reduced the backlash to a minimum. They also allowed the product engineer to relax on tolerances, thereby simplifying manufacturing and increasing production.

As is often the case one problem leads to another. Before backlash was reduced to a minimum, it was found that inertia of the parabola and bracket created another problem. As the dish swung back and forth accelerating and decelerating due to the sine wave motion inherent in the design of an eccentric, the inertia of its mass coupled with lost motion caused chatter. This chatter could be described as a quick acceleration and deceleration during azimuth sweep. When such a scanner was connected to the radar equipment and flight tested, one could be fooled by the picture on the cathode ray tube because two targets instead of one would appear. This phenomenon, naturally, was highly undesirable as the pilot would mistake one target for three or four.

It is known that the simplest ways to reduce inertia effects are to cut down the speed and the weight of the mass. Fortunately, a slow scan was more desirable for search because more pulses of RF energy were received by the scanner while on the target. At the start, wrought aluminum sheet was used for fabrication of parabolas and aluminum die castings were used throughout. With the advances made by Dow Chemical and other firms manufacturing and fabricating magnesium parts, it was pos-

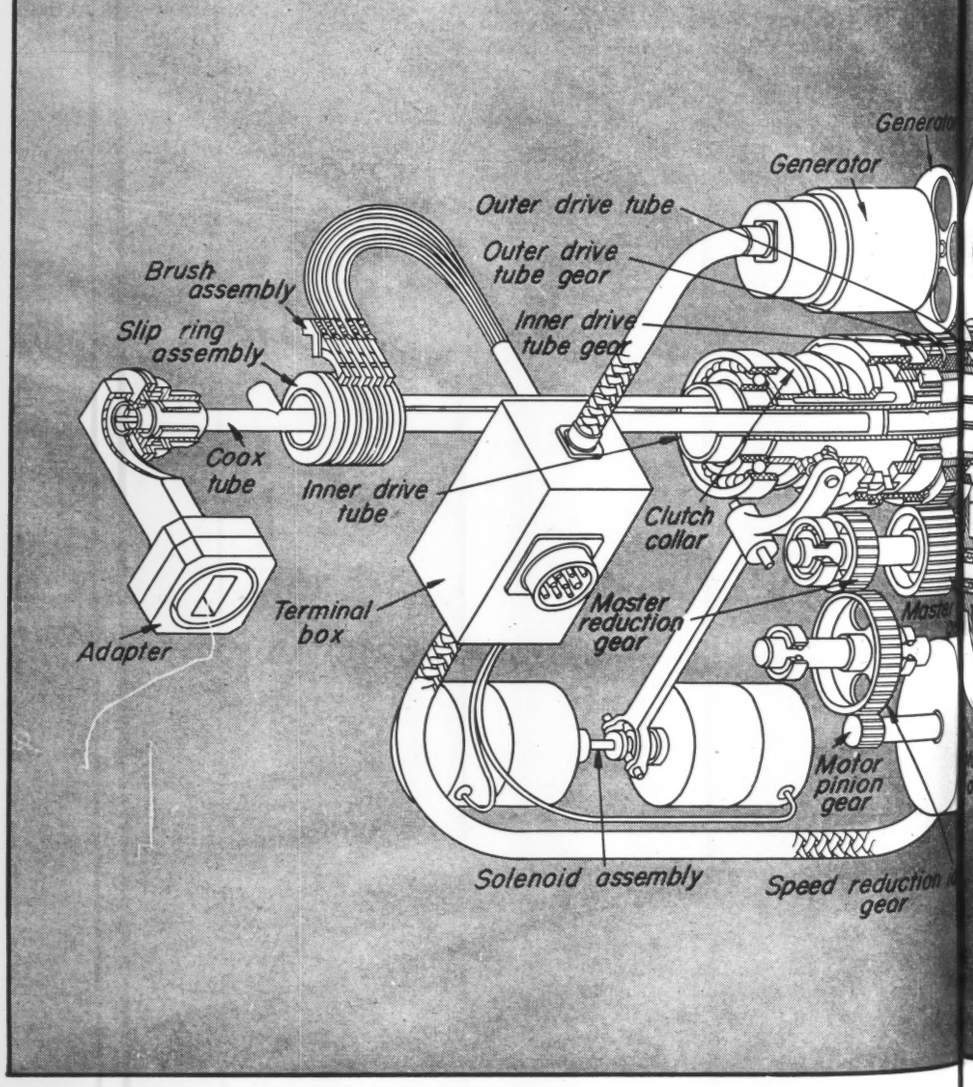


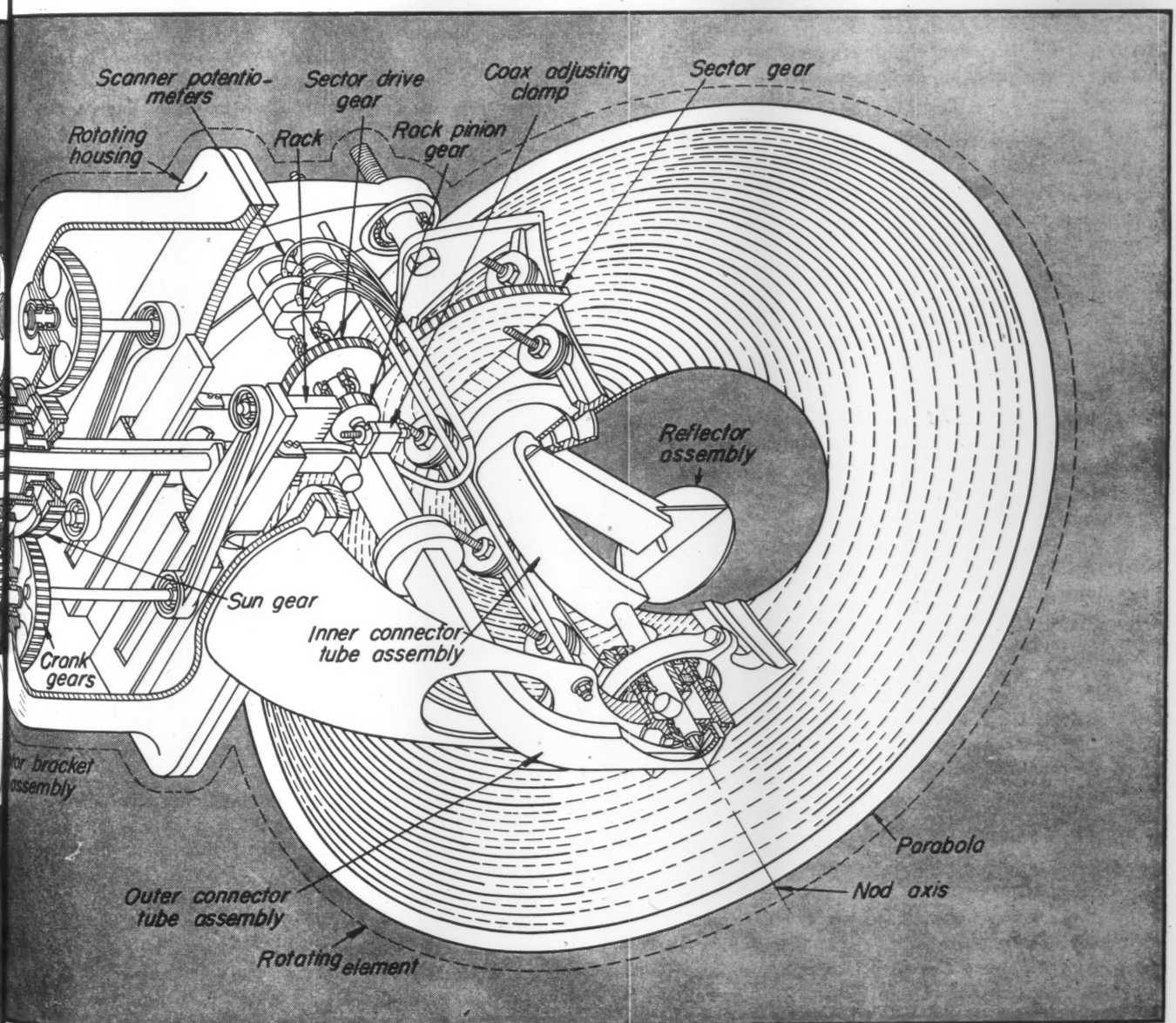
Fig. 3—Schematic assembly drawing of typical airborne scanner showing mechanisms and electrical components that simultaneously rotate and nod the parabola to project a searching beam of microwave energy into space. Units of this type are remotely controlled

sible to form the parabolas from 0.021-inch thick magnesium sheet. The same was true with aluminum die castings versus magnesium die castings. Over a period of six months it was possible to reduce the overall weight of a search scanner approximately 25 per cent.

However, with the advent of scanner production utilizing magnesium parts, the problem of corrosion became much more acute. Various procedures were set up for the protection of magnesium against salt spray; some were effective, some were not.

Various finishes were developed, the most satisfactory being the Dow finishes for magnesium castings and sheet. These finishes were applied to the metal after machining. A minimum of three coats of zinc chromate then were sprayed on, finishing with a hard glossy enamel. Of course the galvanic action of dissimilar metals caused difficulty, such as the aluminum rivets holding the magnesium parabola bracket to the dish. This was solved by driving the rivets right after they were dipped in zinc chromate.

While airborne search radar was being developed and produced, engineers were working against time in the development of lightweight intercept radar. This equipment was similar in electrical design to the airborne search radar. The purpose of the intercept radar, however, was to locate enemy aircraft in the air and to shoot it down after it came within range. The mechanical design of the scanner used in this equipment became fairly complex because the parabola no longer scanned back and forth at a slow rate but rotated and scanned at the same time. These two motions in effect generated a spiral of RF energy that covered a considerable portion of space ahead of the plane. An enemy plane could easily evade a night fighter equipped with an ordinary search radar because the search scan rate is approximately 150 degrees per second, whereas the enemy aircraft might be traveling at over 400 feet per second. Thus the target would disappear off the screen before



the pilot realized it was there.

In the earlier models the dish rotated at a fairly high rate while scanning back and forth through a wide angle. Various problems arose during the development of this unit, the most difficult one being the balancing of the rotating mass. One of the later production models is shown schematically in *Fig.* 3. The section outlined with the dotted line comprised the rotating mass. While this part of the mechanism rotated at high speed the parabola would scan about the nod axis shown. The problem of balancing became difficult as the center of gravity of the rotating mass did not stay the same distance from the rotational axis. This of course was due to the nodding action. Balancing studs were located at strategic points on the rotating and nodding mechanism, and washers could be put on or taken off these studs. The principle of distributing compensating weight about the nod axis and rotational axis balanced the rotating and nodding mechanism. It was one thing to know how to solve this balancing problem but it was another to develop and build a balancing machine for testing the intercept scanners. The Gisholt Machine Co. perfected the balancing equipment now used for checking and testing these intercept scanners.

How Spiral Scan Is Achieved

There are many ways to generate a spiral scan in space. The production model shown in *Fig.* 3 performs the necessary functions by utilizing a differential movement between the inner drive tube and outer drive tube. The drive motor powers the master drive gear through a reduction which in turn rotates the outer drive-tube gear at 1200 rpm.

The inner drive-tube gear also is powered by the master drive gear and since it has one more tooth than the outer drive gear, it rotates at a different speed. When the clutch collar is in the back position, as shown in *Fig.* 3, positive drive is obtained through the inner drive tube, thereby creating a differential of speed between the two tubes.

Rigidly attached to the inner drive tube, the sun gear rotates the crank gears. A crank arm on these gears supplies linear motion to the rack, and the rack in turn supplies oscillatory motion to the sector drive gear, which nods the parabola through the sector gear.

When the clutch collar is actuated by the solenoid assembly, thereby disengaging the inner drive tube gear from the inner drive tube, no relative motion exists between the inner and outer drive tubes. This in effect stops the nodding of the parabola while it is spinning. The parabola is so set during assembly that it still generates a 3-degree (included angle) cone, while the clutch is disengaged. This is done by merely off-setting the parabola 1½ degrees from the spin axis. This conical scan was used by the pilot after he had closed in for the kill. It was called "gun sight scan." The generator and two potentiometers are attached to the scanner for the purpose of supplying electrical information as to azimuth and elevation position of the beam to the indicators. A two-phase sinusoidal voltage, 90 degrees apart in phase, is produced by the generator, which revolves at the same rate as the scanner. This voltage gives elevation and azimuth information. The nod angle information of the scanner is supplied by the potentiometers which are connected in such a way that the nodding of the scanner modulates the sinusoidal voltage.

In order to eliminate lost motion and backlash the potentiometers are assembled direct on the sector drive gear shaft. This necessitates the use of slip rings. The RF transmission line requires two rotating joints: The one at the back of the scanner is purely rotary, the other, positioned on the nod axis, is oscillatory.

As the rotational speed of the gears driving the scanner necessitated the use of oil for lubrication, the problem of adequate oil seals arose. It was impossible to use an ordinary type oil seal, because of its weight. Also, one drop of oil splattered against the radome, housing the scanner in the plane, would reflect the RF energy back into the radar, thereby presenting a false target on the indicator. Many different types of oil seals were tried before a satisfactory one was found. In effect, the oil seal used creates a baffle, which in turn generates a wiping action to prevent leakage. Many other problems were experienced during the production of the intercept scanner, but were of similar nature to those already discussed on the search scanner.

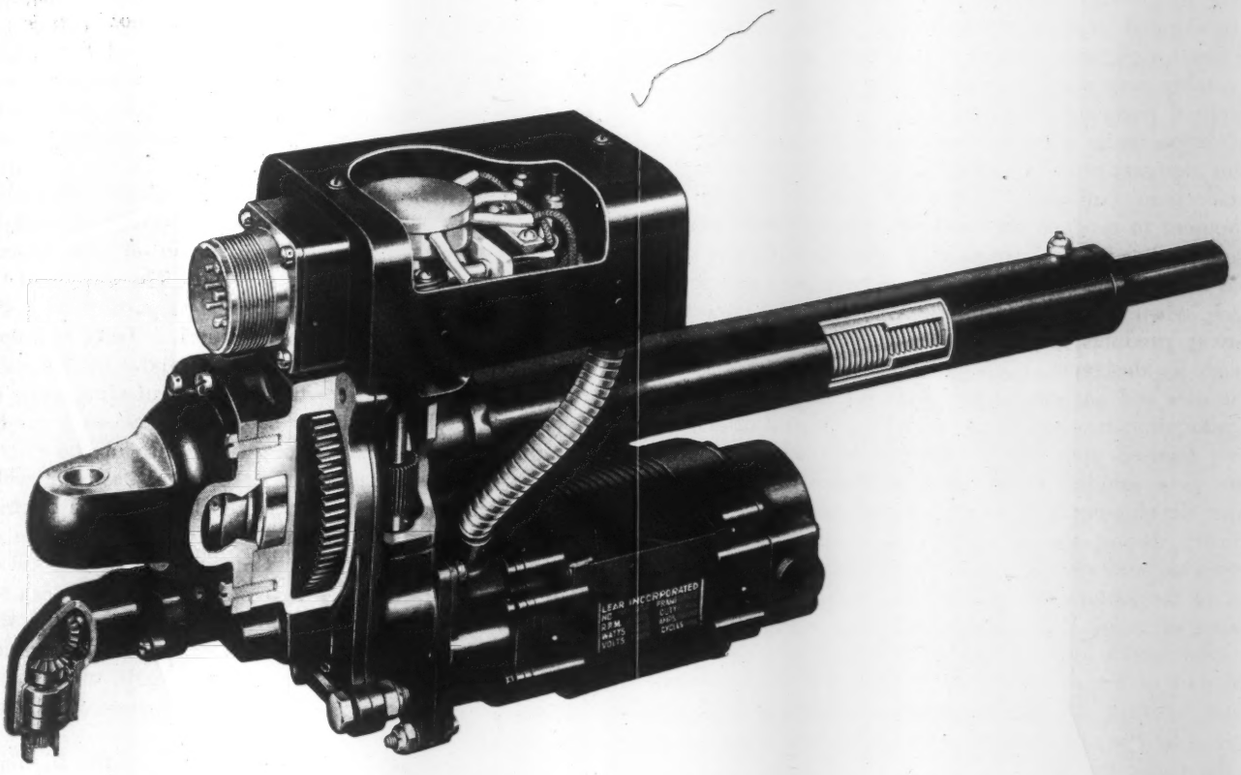
The next logical step in improving the usefulness of lightweight airborne radar is to combine both the search and intercept gear into one compact unit. This would mean that no enemy surface vessel within a fairly long range of the search radar, or no enemy aircraft within the range of the intercept radar would be safe from attack by a night fighter equipped with this new gear. Due to security reasons, the various mechanical and electrical problem in such equipment cannot yet be discussed.

Facts Versus Opinions

IN a talk entitled "Imagineering for the Future," delivered recently before the Columbus Technical Council, William B. Stout expressed the belief that facts must supplant opinions if further progress is to be achieved. Stating that until experimental work was begun in this country, opinion and debate were the only methods of arriving at conclusions, he relegated these to politicians and others who are unwilling to recognize that research—the search for truth—will be far more powerful than argument in the future. "This concept," he said, "must be made a part of all modern education if our school graduates are to make their places in the world of tomorrow."

Stout contended that properly conducted science could, if it so desired, rule the world, and added that only those nations which continue to advance in scientific endeavor can hope to survive.

Commenting on the future of automobiles, Stout stated that real progress in this field would not come from the large producers "because they dare not produce a product which will result in a monetary loss," but rather "it is up to the few with original ideas to show the way, even though they gain little in money for their work."



Matching the Small Motor to the Job

By Ie Moyne Dabbs
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Lear Inc., Grand Rapids, Mich.

CONSIDERATION of any machine drive or control problem cannot be carried to a conclusive decision until a substantial amount of research and study has been given to the motive force required in the actuating or operating elements. With the advent of the tremendous engineering problems involved in the design of equipment during the recent war, engineers in every type of activity were confronted with problems where their old stand-by "rule of thumb" method for selecting power devices failed to supply the proper power where and when it was needed.

A new trend in power source development has been brought into the picture

by the numerous engineering problems that have come before motor and machine designers during this period of accelerated engineering activities. As an example of this trend, designers, instead of specifying a certain motor by catalog page number or model number as in the past, submitted pertinent data and information concerning the application under consideration with the request that the motor designer provide a power unit meeting the particular specifications outlined. This entailed research and development to produce the most suitable unit for the conditions outlined. As a result of this trend, numerous new ideas in fractional-horsepower motors have been developed which, when considered in the light of new and important postwar products, present an entirely new field of approach for designers.

Studies and analyses of problems submitted by various manufacturers resulted in a tremendous amount of activity being focused upon the application of packaged power units as a solution to actuating problems. One of the major developments of the fractional horsepower motor industry during the war centered around the "fastop" electromagnetic clutch and brake which, in reality, was a part of the motor design necessary for the proper functioning of many linear and rotary type actuators. This electromagnetic clutch is shown in *Fig.* 1 and is an integral part of the motor design, housed within the overall motor housing. On direct-current applications, it is energized by the same current source used for the operation of the motor proper.

Because of the wide use of 110-volt alternating current in most industrial applications, it was necessary to develop a clutch that was reliably actuated by alternating current. In this respect, a manufacturer of business machines required precision positioning of a motor-driven device. It was important that the advantages of weight and space saving permitted by the use of built-in electromagnetic clutches be considered. The former method of breaking the power source instantaneously from the driven mechanism employed the use of the commonly known dog-type clutch which was cumbersome in design, noisy, subject to considerable wear, and expensive because of the number of parts involved. All these objections were eliminated by substituting the electromagnetic, built-in clutch actuated by the same electrical switch which starts the machine in motion.

When used for an electromagnetic clutch, alternating current does not permit the flexibility of design available in direct-current applications, because of the inherent characteristics of alternating current. The design of this clutching device involved a radical departure from that employed in the direct-current clutch. Tests and operating data on actual working models now in the manufacturer's plant have shown indications of eliminating the dog-type clutches originally considered necessary for this application. In addition to this the use of the electromagnetic clutch, separate from the motor itself but within the same mechanism and energized by the same electrical circuit, made it possible to eliminate the use of an additional motor in this business machine. The original design required the use of two motors, one of which was actuated by a cam-driven device operating off the shaft of the second motor. The use of this separately energized clutch, wired into the same control circuit, obviated the second motor, thereby reducing costs, maintenance, space and weight.

As another example, a manufacturer of textile machinery recently presented an actuating problem involving opening and closing a heavy steel door at a predetermined rate. In conjunction with the opening and closing of this door, it was necessary to open and close a steam inlet and outlet valve. Previously, the door and valve had been operated hydraulically necessitating the continuous operation of a ¾-horsepower pump motor during the working schedule of the plant. We were requested to analyze this problem with regard to simplifying design, reducing the bulkiness and number of parts involved, eliminating maintenance and installation problems, and in general lowering the over-all cost of this device.

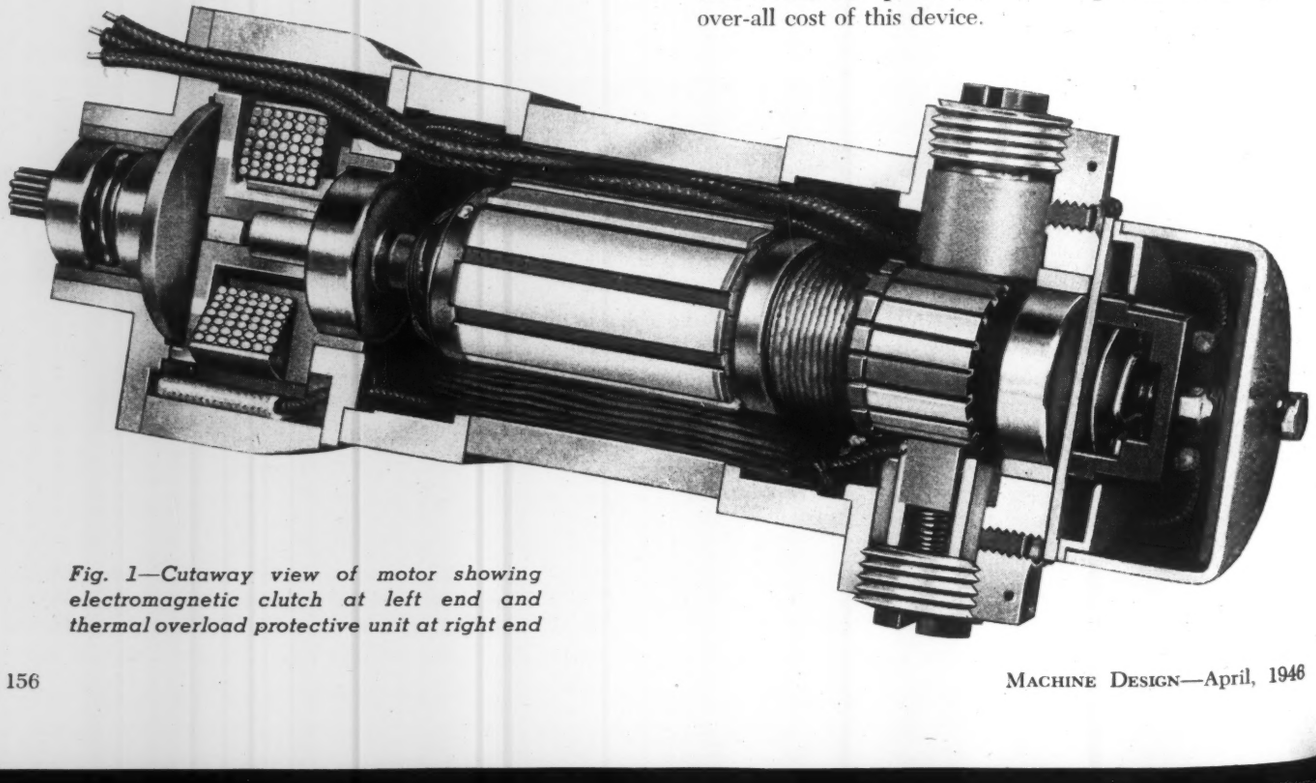


Fig. 1—Cutaway view of motor showing electromagnetic clutch at left end and thermal overload protective unit at right end

At engineering discussions in our own plant, as well as with the design engineers of the textile machinery, it was first decided to use whatever method or device was presently available, rather than to develop an entirely new design for the machine manufacturer's problem. A comparison of the load requirements with the performance characteristics of a group of available "wartime" units indicated that a certain type of an auxiliary actuator for aircraft was suitable. After this decision was made it was only a matter of providing a motor winding for the linear actuator in

Motor Application Data

A. Application
1. Field of use .....
2. Machine to be driven .....
3. Description of operation .....

B. Power Supply
4. A-C: Frequency (cycles per sec) ..... Phase ..... Volts .....
5. D-C: Volts .....

C. Required Output: At Motor shaft (hp) .....
At gearbox shaft (hp) .....
6. Normal Requirements: Type motor desired .....
(a) Watts ..... or Horsepower, Full-load speed (rpm) .....
(b) Permissible speed regulation (%) ..... to .....
(c) Full-load running torque (oz-in.) .....
Starting torque (oz-in.) .....
7. Maximum load conditions
(a) Horsepower ..... Speed (rpm) .....
Starting torque (oz-in.) .....

D. Performance
8. Direction of rotation when facing shaft extension: CW .....
CCW ..... Reversible while running .....
Reversible when at rest .....
9. Continuous duty ..... Intermittent duty .....
10. If intermittent duty, running period ..... and rest period .....
11. Uniform speed ....., or variable speed .....
12. Does application require accurate positioning of output shaft when stopping such as can be accomplished with clutch and brake?

E Miscellaneous Data
13. Is brush type motor suitable? .....
14. Give end thrust load if present .....
15. Motor mounting position .....
16. Range of ambient temperature .....
17. Condition of ventilating air .....
18. Details of shaft extension (flat, slot, pinion, length, etc.) .....
19. Degree of enclosure of space where motor will be installed .....
20. Desired mounting dimensions ..... and maximum over-all dimensions .....

F. Special Requirements
21. Is light weight of value? .....
22. Small size? .....
23. Is quietness important? .....
24. Are there any restrictions on shaft end play? .....
25. Terminal or lead requirements other than standard .....
26. Is automatic thermal protection required? .....
27. Must motor be totally enclosed? ..... Explosion proof? .....
Drip proof? .....
28. Brake ..... Clutch and brake .....
29. Type of bearings: Ball ..... Plain ..... Is drive end bearing subject to grease or oil under pressure? .....

G. Production Data
30. Anticipated annual quantity required .....
31. Price range per unit that can be considered ($) .....
to .....

order to satisfy the power source specifications of the manufacturer. Sample units of the type shown in the head illustration wound to meet the specifications of the manufacturer, were supplied and installed on a test machine.

Exhaustive tests were then run on the machine in an effort to determine the efficiency, performance and over-all reliability under actual service conditions. These tests were conducted under conditions which were much more rigid than is normally expected under day-in and day-out use. The results of these tests were so satisfactory to both engineering departments that no further design studies were considered necessary. Typical characteristics of this motor are shown in *Figs.* 2 and 3.

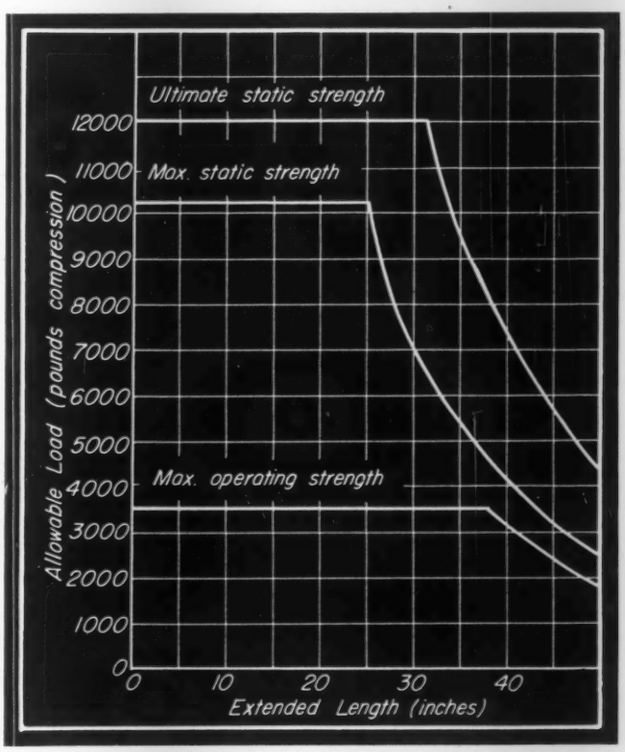
The original design included one ¾-hp, continuous duty 110-volt single-phase, 60-cycle, 1725 rpm electric motor; one hydraulic pump of sufficient capacity to operate the hydraulic actuators; two hydraulic actuators, one to open and close the door and another to open and close the steam valves; hydraulic piping necessary to provide proper functioning; and the mounting base and cover to house the motor and hydraulic pump. This pump housing cover was approximately 18 inches by 18 inches by 3 feet and was 18 gage sheet steel. In addition to the above equipment, certain electrical switches meeting underwriters standards were required on the side of the machine.

In contrast to the foregoing equipment, the new power unit provided one 14½-pound linear actuator electrically driven by a ⅜-hp motor with an overall installation dimension of 26 inches in the retracted length and 34 inches at the extended or open door position. In width, and height, this unit was approximately 7 inches. The simplified engineering of the entire installation required only the space originally occupied by the hydraulic linear actuator. As far as installation and operation in the machine was concerned, the only other device necessary was the provision of an electrical switch sufficient to handle the current requirements for the ⅜-hp motor. Study and analysis showed clearly that the door and valve opened only at specified times, and these periods and length of operation were well within the capabilities of the duty cycle of the aircraft intermittent type electric actuator.

As a result, the electric actuator required current only when the door and steam valve were being opened or closed, representing less than 20 per cent of the total time the machine was in operation. Continuous operation, however, of the ¾-hp motor was required to maintain pressure in the hydraulic system.

Much of the advancement made in power unit design has resulted from the study and analysis of detailed in-

Fig. 2—Allowable load curves for linear actuator



formation supplied by the machine designer.

Preliminary discussion between the engineering staffs of the machinery builder and the motor manufacturer have been shortened and have become more pertinent when the machine designer incorporated his requirements on a simplified motor application data sheet. Shown tabulated are the data requested in one of the many forms available for this purpose. The information supplied presents a complete picture of the application and its requirements to the motor designer.

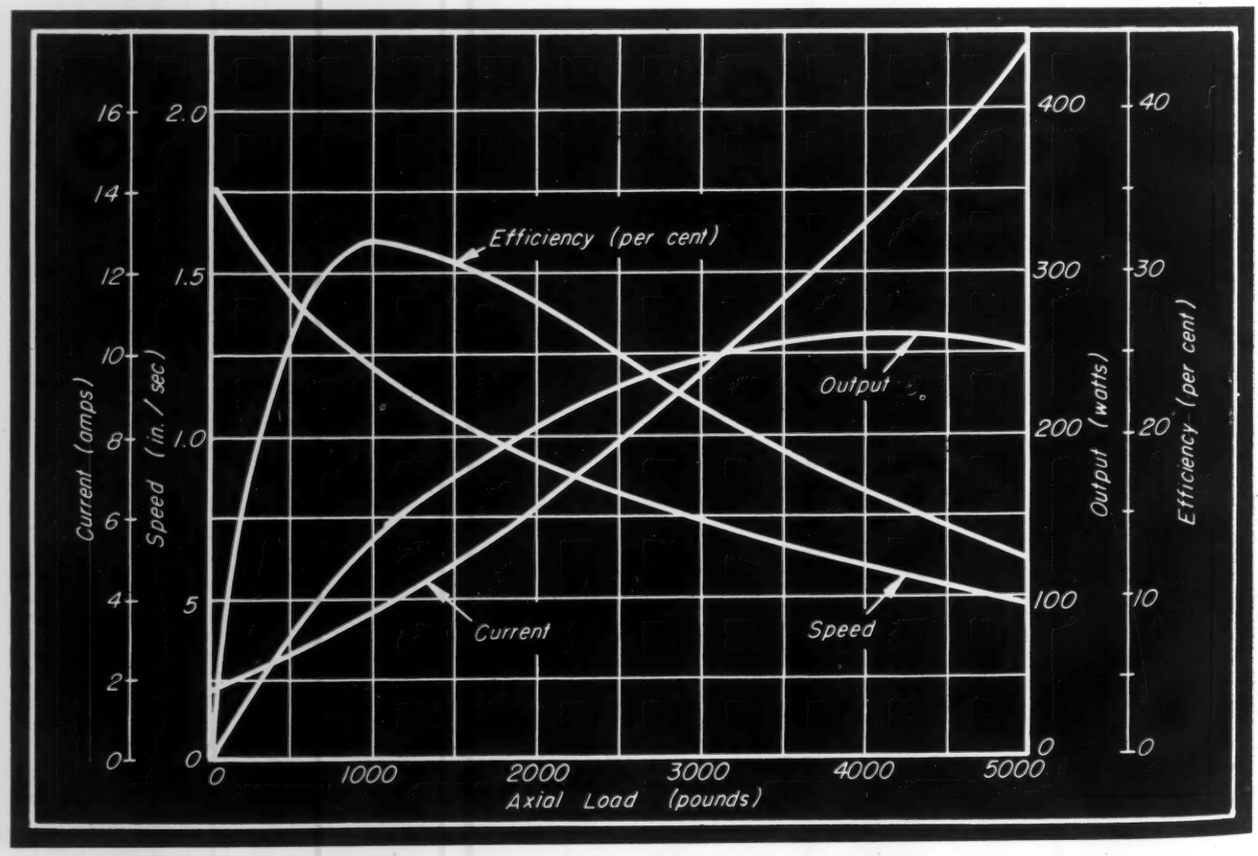
After careful study and analysis of the data by the concerned individuals of both engineering departments, recommendations are made based upon the availability of motors and actuators already designed. When the motor manufacturer fails to find any suitable device already available as far as design is concerned, recommendations are made for a motor or power package to be developed to suit the specifications listed.

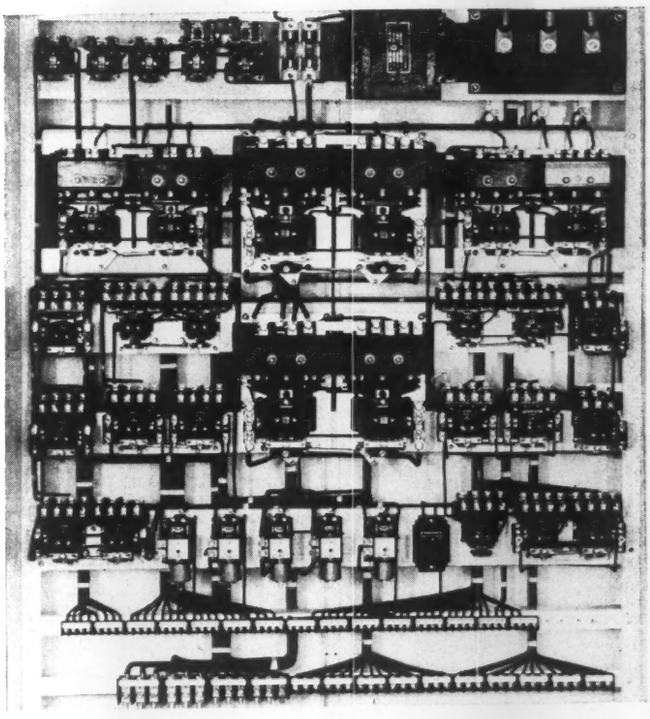
Analysis of numerous motor application data forms has definitely established the fact that many devices ordinarily powered by "shelf" type motors were overpowered, thereby incorporating excessive weight, increased production costs and other disadvantages to both manufacturer and consumer. This was probably due to the lack of coordination between the machine designer and motor engineer in the past. Machine designers, heretofore, have been in the habit of specifying the motor requirements with little or no attention to the design problems involved. Motor manufacturers, on the other hand, have been prone to fill these demands with a standard or "shelf" type motor without regard to the specific needs presented by the design problems. Close co-operation with regard to each individual requirement, however, has produced "miracles".

Power units have been developed for specific applications in aircraft for actuating flaps, butterfly valves, trim tabs, automatic direction finder loops, etc. These devices include linear actuators with 2, 3, 4, and 5 position limit switches, linear actuators with either liquid filled or electronic automatic temperature control, linear actuating devices with additional take-offs so that flexible shaft driven screwjacks could be powered from the same source, rotary type actuators employing both the electromagnetic clutch and a manually overriding disk type electric clutch. Such units have found or can find numerous present-day and future applications in the industrial and domestic fields. Included in this category are business machines, vending machines, hair dryers, fruit juicers, food mixers, and other home appliances, and heavy or industrial machines in which they are used as auxiliary or automatic operating devices. In a great many instances, they perform the same job within a machine as is ordinarily accomplished by the use of gear-reduction drives, linkages, levers and cams. Because necessity forced it, motor designers have developed all of this into one unit, resulting in compactness heretofore unknown.

Application possibilities of rotary and linear actuators, fractional-horsepower motors and other packaged power units are as tremendous to the general machine design field in the future as they have been in the aviation field.

Fig. 3—Characteristic performance curves for actuator shown in head illustration





Control Diagrams— an Aid to Design

By F. L. Fisher
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ELEMENTARY control diagrams, often called schematic or line diagrams, are extremely useful to designers working with electrical equipment. Those who have not used them will find that, with a little study, such diagrams can be of great help. They give a clearer picture of the apparatus and functions involved than can be obtained from a wiring diagram.

Layout of the elementary diagram is the first step in the design of any control system and is the means for determining its proper functioning as well as for specifying the devices required. It may also be used for the panel layout in locating the material for the best wiring arrangement. From it the panel wiring dia-

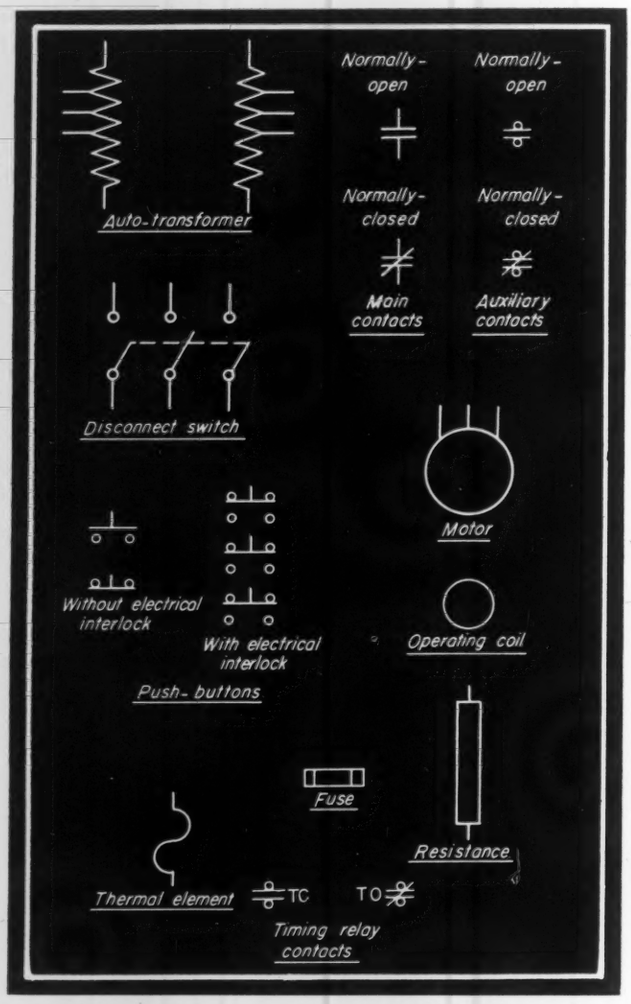


Fig. 1—Standard symbols employed in elementary control diagrams facilitate drafting and reading

gram can be made after the panel layout has been completed. Later it may be used by the test department in checking circuits. After installation, elementary diagrams are often used by plant electricians and maintenance men in locating troubles in control circuits.

In an elementary diagram all motors, control devices and the wiring between them are shown in a simplified form. Unlike wiring diagrams, no attempt is made to show the relative location of devices in the system or even between contacts and coils of the same device. Connections from devices to the control lines are drawn as straight lines wherever possible with a minimum of crossed lines. All device markings should be identical to the device markings on the wiring diagram.

Diagrams Should Show Power and Control Circuits

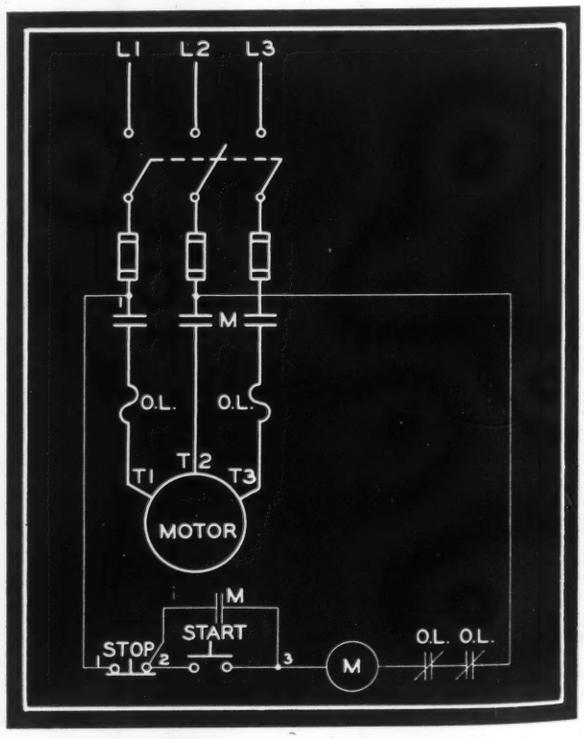
In making elementary diagrams it is best to draw the power circuits first. They will include all circuit breakers or disconnect switches and motor main circuits. An elementary diagram is never complete unless both main and control circuits are shown. After the main circuits have been completed a line is drawn down each side of the paper for control lines. Between these two lines are drawn the various control devices in straight alignment wherever possible. In working out a control problem it is not always possible to draw a good elementary diagram the first time. It may be necessary to redraw it once or twice before all unnecessary crossed lines are eliminated.

Symbols shown in *Fig.* 1 and used in the following illustrations are American Standard symbols. The American Standards Association publishes two booklets listing sysbols which are standard in control work: *Graphical Symbols for Power, Control and Measurement*, and *Graphical Symbols for Electronic Devices*. The diagrams to which reference is made in the following discussion may seem elementary to some readers. It should be borne in mind, however, that an attempt is being made to help those not familiar with schematic diagrams nor their advantages.

Are Easier To Read

In *Fig.* 2 is shown an elementary diagram for a simple alternating-current combination starter with a fused disconnect controlled by a separate mounted start-stop, momentary-contact pushbutton station. It is taken for granted that an elementary diagram is not necessary to determine how this type of starter operates but when compared with the wiring diagram in *Fig.* 3, one can see the advantage of the elementary diagram for analyzing the operation of equipment. One glance at the diagram in *Fig.* 2 shows that if the disconnect switch is closed, the coil of the starter is energized when the start button is pressed. When the starter contacts close, the motor is connected to the lines and the auxiliary contact on the starter maintains

Fig. 2—Elementary diagram for a simple combination starter. Heavy lines indicate power circuit



the circuit to the coil of the starter after the start button is released.

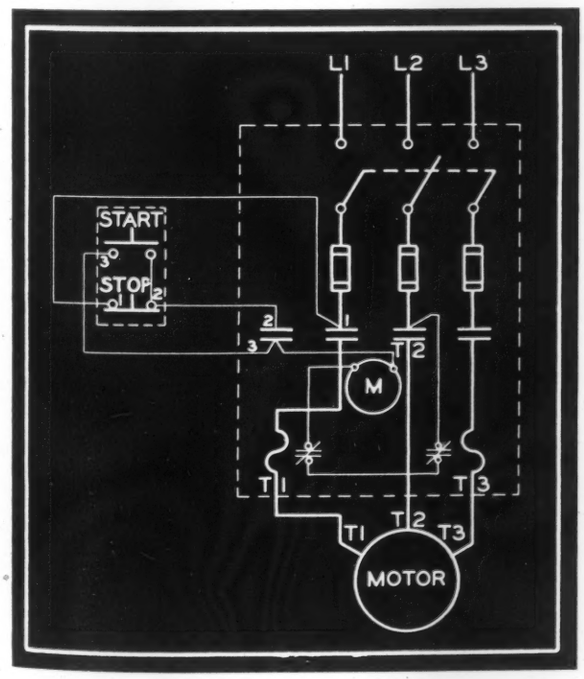
Referring to the wiring diagram in *Fig.* 3, one does not find it difficult to follow the operation, but it requires more time to see what takes place in the operation. It should be noted that the elementary diagram shows all devices and terminal markings shown on the wiring diagram but does not show the relative location of the starter coil, maintaining contact or overload-relay pilot contacts.

Comparison Shows Advantages of Schematic

In *Fig.* 4 is shown an elementary diagram of an across-the-line reversing starter with a fused disconnect switch. The starter in this case is controlled by a forward, reverse, stop pushbutton station. *Fig.* 5 shows the wiring diagram for the reversing across-the-line starter. Comparing this diagram with the elementary diagram and bearing in mind that both diagrams show the same devices, wiring and terminal markings, it is again obvious which of the two is easiest to read and understand.

Before going to a more complicated starter let us check the operation of the starter shown in *Fig.* 4, starting with the main circuits of the starter. Assuming the disconnect switch is closed, when the contacts of the forward switch *F* close, lines 1, 2 and 3 are connected to motor terminals *T*1, and *T*2 and *T*3, respectively. The circuits from *L*1 to *T*1 and from *L*3 to *T*3 pass through the overload-relay heaters on the starter. With the forward switch *F* closed, the motor revolves in one direction. Assuming the

Fig. 3—Wiring diagram for starter in Fig. 2, illustrating how much more readily the schematic elementary diagram may be read



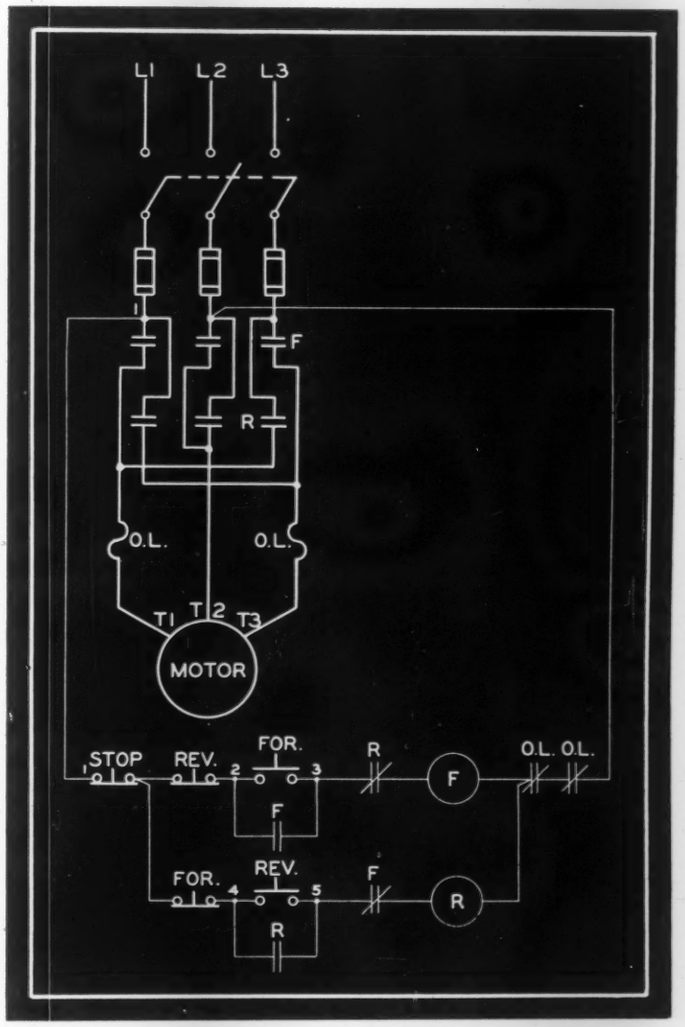


Fig. 4—Across-the-line reversing starter shown by an elementary diagram

forward switch contacts *F* are opened and the contacts of the reverse switch *R* are closed, lines 1, 2 and 3 are connected to motor terminals *T*3, *T*2 and *T*1, respectively, and the direction of rotation of the motor is reversed. Opening of the *R* switch contacts will de-energize the motor.

Contacts and Coils Are Not in Relative Positions

Considering the control circuit of the diagram in *Fig.* 4, it will be noted that the forward and reverse pushbutton units each have a set of normally-open and a set of normally-closed contacts. The contacts are not placed in their relative positions on the elementary diagram as they are on the wiring diagram *Fig.* 5. This is done to eliminate the crossing of lines on the elementary diagram. It might be well to mention again at this point the fewer the crossed lines in an elementary diagram, the more easily it can be read.

Assuming the disconnect switch is closed and an operator presses the forward pushbutton, normally-open contacts of the forward pushbutton unit will be closed and the

normally-closed contacts will open. The opening of the normally-closed contacts breaks the circuit to the reverse pushbutton unit. Closing of the normally-open contacts completes the circuit energizing the forward switch coil, this circuit being from *L*1 through the stop pushbutton contact, the normally-closed contact of the reverse pushbutton, the normally-open contact of the start button, the normally-closed auxiliary contact on the *R* contactor, the *F* coil and the overload-relay pilot contacts to *L*2. The closing of the normally-open auxiliary contact on *F* maintains the feed to the *F* coil when the forward pushbutton is released.

It will also be noted that when the *F* switch closes, the normally-closed auxiliary contact on the *F* switch opens in the circuit to the *R* coil making it impossible to energize the *R* coil until the *F* switch coil is de-energized and its normally-closed contact recloses. Pressing the stop button will open the circuit, de-energizing the *F* coil and its contacts will open. Pressing the reverse button will also de-energize the *F* coil and when its normally-closed auxiliary contact recloses, the *R* coil will be energized.

Comparing the wiring diagram in *Fig.* 3 with that in *Fig.* 5, the wiring for *Fig.* 5 is much more difficult to trace although only one additional contactor is utilized. Comparing *Fig.* 4 with *Fig.* 2, it will be noted either one can be read easily.

Required Components Are Shown

An elementary diagram for an automatic reduced-voltage autotransformer type starter is shown in *Fig.* 6. When referring to the advantages of elementary diagrams, it was stated that they may be used to determine the devices required to build a control. On examining the main circuits shown in *Fig.* 6, contactor *MS* has five main contacts and contactor *MR* has three main contacts. Two overload relays and an autotransformer are required and in addition three line terminals and three motor terminals. That is the complete list of material required for the power circuit.

Referring to the control circuit, the equipment is controlled by a start-stop pushbutton station. Also one normally-open and one normally-closed contact on contactor *MS* and one normally-closed contact on contactor *MR* are required as well as one timing relay with one normally-closed contact, time-delay on opening. Also needed are two single-pole relays 1*CR* and 2*CR* for handling the coil circuits of *MS* and *MR* contactors. One control relay 3*CR* having two normally-open contacts completes the list of material to build the starter. The only thing left to finish the design is to select the proper size contactors, autotransformer, overload relays, and control relays. The size of the motor determines the size of the contactors, autotransformer and overloads, and the capacity of the control relays depends upon the size of the main contactors and the current taken by the contactor coils.

Assuming there is power on lines *L*1, *L*2 and *L*3 in *Fig.* 6, the operator presses the start button completing the circuit to the coils of timer *T* and control relay 1*CR*. The circuit is from *L*1 through the stop button, start button, normally-closed auxiliary contact of *MR*, and timer coil *T* to the overload-relay pilot contacts. It also is through 1*CR* relay coil and the timer contact to the overload pilot contacts. The circuit is completed through the overload-relay pilot contacts to *L*2. The timer coil, being energized, starts its timing cycle. Coil 1*CR* now being energized, closes its normally-open contact, energizing contactor coil *MS*. The closing of *MS* connects the autotransformer to the line and the motor to the taps

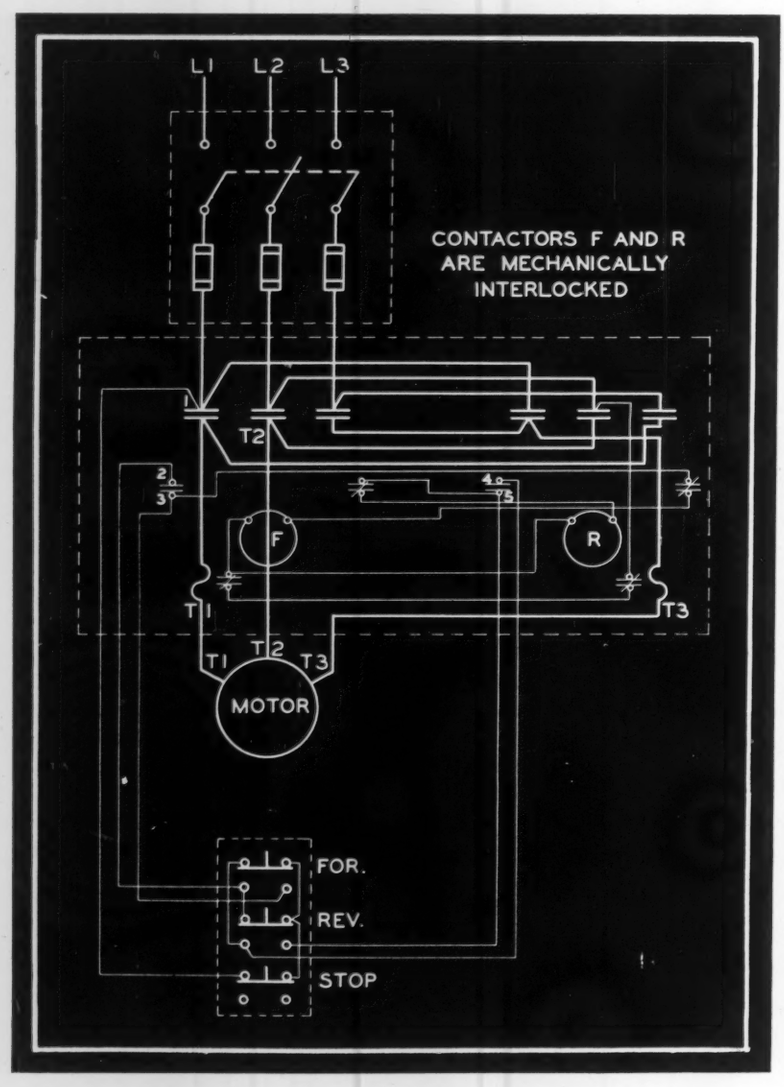


Fig. 5—Wiring diagram for starter in Fig. 4. Although only one more contactor is used than for the simple combination starter, diagram has become much more complicated, making it difficult to read

of the transformer so that the motor starts on reduced voltage. At the same time *MS* main contacts close, the *MS* normally-closed auxiliary contact opened in the circuit to 2*CR*. Also the normally-open auxiliary contact of *MS* closed energizing the coil of 3*CR* relay. One contact of 3*CR* closed containing the feed to the timer coil, 1*CR* relay coil and to 3*CR* coil. The second contact of 3*CR* closed in the circuit to 2*CR* coil but is not effective at this time since the *MS* normally-closed contact has been opened previously.

Interlock Prevents Operation of Start Button

When the timer *T* completes its timing cycle, its normally-closed contact opens, de-energizing the coil of 1*CR* relay. Relay 1*CR* opens energizing the coil of *MS* contactor. The opening of this contactor disconnects the autotransformer and opens the connection from the autotransformer to *T*2 of the motor. The normally-open auxiliary contact on *MS* opens and the normally-closed auxiliary contact on *MS* closes energizing 2*CR* relay coil as the contacts of 3*CR* are closed. The closing of 2*CR* relay contact energizes the coil of *MR* contactor. The closing of *MR* main contacts connects the motor to the line. The opening of the normally-closed contact on *MR* locks out 1*CR* and *T* coils so they cannot be energized if the start button is pressed while *MR* is closed and the motor running.

Tripping of the overload relays or pressing the stop button will de-energize 2*CR* and 3*CR*. The opening of 2*CR* contact will de-energize *MR* contactor coil. The opening of *MR* contacts disconnects the motor from the line.

To further illustrate the use of the elementary line diagram, an actual control problem will be discussed. A machine will require three motors, a 50-hp head motor, a 20-hp head motor and a 25-hp feed motor. In the locality where this equipment is to be installed the power company requires reduced voltage starting on motors over 25 horsepower.

Specifications state that neither the 20 nor 25-hp motor shall be started during the starting of the 50-hp motor. Also the starter for the 50-hp motor shall be a primary-resistor reduced-voltage starter. A nonfused disconnect shall be provided ahead of the starting equipment and the control circuit shall be fused.

Control for the head motors shall be arranged so that in the event of an overload on either head motor, the feed motor shall be shut down. If the overloads on either of the head motors trip and the overload is relieved within five seconds after the feed motor has been stopped, the feed motor can again be started. If the overload condition on either head motor is not relieved within five seconds after the feed motor has been stopped, the entire machine must be shut down.

It shall be possible to run either one or both of the head motors and the feed motor at the same time. The feed-motor control shall be arranged so that the motor will only run in the forward direction and will be plugged to rest on stopping. The feed motor shall be de-energized when starting either of the head motors.

The elementary diagram which provides all of the features required by the specification is shown in *Fig.* 7. In making an elementary diagram of this kind, the nonfused disconnect and the three power lines for feeding the starters are drawn first. Then drawn in order are the main circuits for the reduced-voltage starter for the 50-hp head motor, the across-the-line starter for the 20-hp head motor, and last, the cross-the-line reversing starter.

Next are drawn the two control lines showing the two

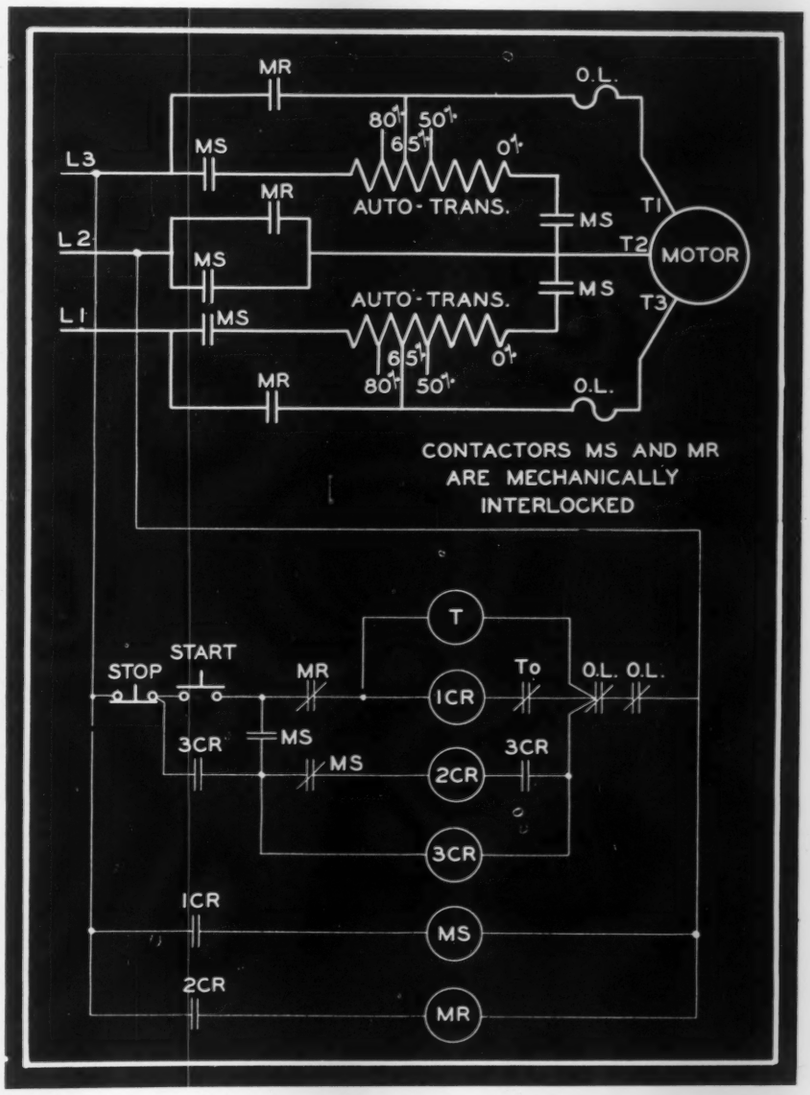


Fig. 6—Elementary diagram for an automatic reduced-voltage autotransformer type starter clearly shows control circuit as well as the number of devices

control fuses called for in the specifications, followed by the master control relay and the devices for controlling it. After that would be worked out the control for de-energizing the master relay when overloads on the head motors exceed five seconds. Following these details would be drawn the control circuits for the head-motor starter and the feed-motor starter.

No doubt at this stage the diagram would have a number of crossed lines and it would be necessary to redraw it, eliminating unnecessary crosses.

Checking through the operation of the equipment it will be noted that pressing the "on" button energizes 1*CR* relay coil. The contacts of 1*CR* close, one contact maintains the feed to 1*CR* coil and the second contact completes the circuit to the balance of the control. Immediately 2*CR* coil is energized, one of its contacts opens in the circuit of 2*CR* relay and the second closes in the circuit feeding *F* and *P* coils.

Pressing No. 1 start button energizes *S* contactor and *IT* coils. The contacts of *S* contactor close connecting the resistors in series with the motor. A normally-open auxiliary contact on *S* contactor maintains the feed to *S* coil when the start button is released. A normally-closed auxiliary contact on *S* contactor opens the circuit to the start pushbutton for No. 2 head-motor starter and the feed-motor starter.

After *IT* timer has completed its cycle, its normally-open contact closes energizing the *R* contactor. The main contacts on *R* contactor connect the motor to the line. A normally-open auxiliary contact on *R* contactor closes in parallel with timer *IT* contact and the normally-closed auxiliary contact on *R* opens, de-energizing *S* contactor and *IT* timer. When *S* contactor is de-energized its normally-closed auxiliary contact recloses, completing the circuit so either No. 2 head motor or the feed motor can be started.

Pressing No. 2 start button energizes *M*1 coil. The contacts of *M*1 contactor close connecting No. 2 head motor to the line. Pressing the feed start pushbutton energizes the *F* contactor and *P* relay coils. The closing of the main contacts on the *F* contactor energizes the feed motor in the forward direction.

In case of an overload on either head motor, the overload relay pilot contacts open de-energizing 2*CR*. The normally-open contact on 2*CR* opens in the circuit to *F* contactor and *P* relay de-energizing both. The contact of *P* relay is now closed and when the normally-closed contact on *F* contactor recloses, *R* contactor is energized. The main contacts of *R* contactor close, reversing the connections to the feed motor, plugging it to rest. When the feed motor stops *P* relay opens de-energizing *R* contactor.

At the time 2*CR* was de-energized its normally-closed contact closed in the circuit to 2*T* coil energizing it. If the overload condition is relieved in less than five seconds the overload pilot contacts reclose, energizing 2*CR* coil. Coil 2*T* is de-energized and it is possible to start the feed motor.

If the overload condition lasts for five seconds the normally-closed contact of 2*T* opens in the circuit of 1*CR* coil, de-energizing it, and in turn de-energizing both head motor starters.

With a little study of elementary diagrams, a better understanding of control equipment can be gained and considerable time can be saved in laying out the circuits or locating troubles in control equipment.

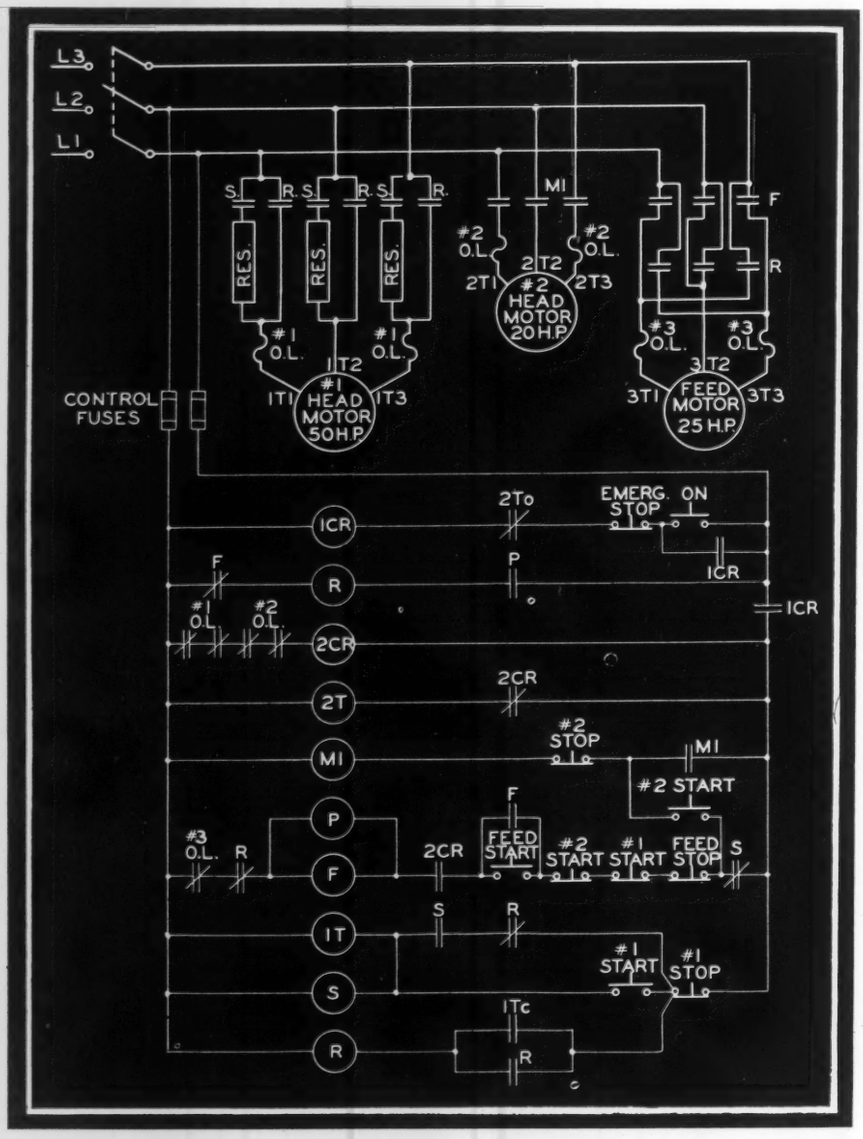


Fig. 7—Diagram for machine utilizing two head motors and one feed motor. When main head motor is starting neither of the other motors can start. Time-delay overload protection is also incorporated as well as reduced-voltage starting

MACHINE DESIGN *Editorial*

Toward More Automatic Control!

DEVELOPMENTS in peacetime machines that are increasingly coming to light indicate the extent to which the accumulation of knowledge gained throughout the war is now being put to effective use in the engineering departments of machinery manufacturing plants. It would be difficult to name a single machine classification in which radical improvement in design is not taking place as a result of wartime progress.

Although such improvements affect practically every phase of design, it is in the field of machine drives and controls that particularly outstanding advances are being made, and through which greater and greater automaticity in operation is being achieved. An especially pertinent example of this is the new "automatic brain" for airplanes which, operated only by pushbuttons prior to take-off, is said to be capable of controlling the flight of a plane from one location to another hundreds of miles away without the necessity for any manual operation whatsoever. Even take-off and landing are automatic. It is believed by the Air Technical Service Command, now testing the device, that this promises to be one of the most outstanding achievements ever made in flight engineering.

An achievement in an entirely different field in combining various methods of machine drive and control stands to the credit of the designers of a machine for milling rock-bit cutters (discussed in the leading article in this issue) which is operated by a combination of electrical, hydraulic and mechanical devices. Combined methods of the type employed in this instance offer extreme flexibility in both design and operation and in many cases provide the answer to problems that would be impossible to solve by any one of the three methods used singly.

Designers of automatic transmissions for passenger cars and busses probably are in the lead in combining the widest variety of drive and control methods in one device, in that they utilize not only hydraulic, electrical and mechanical means but, in some transmissions, pneumatic also. Experience gained as a result of the development and performance of mobile wartime equipment has been put to excellent use in designing the new transmissions.

The fund of information already available and still to be released in connection with the design of war machinery, as well as the resulting trend toward increased automatic operation, cannot be overlooked. There is no question that automaticity, one of the most important design considerations of today in all types of machines, will become even more vital in the years ahead.

L. E. Jermy

ASSETS to a BOOKCASE

Production Illustration

By John Treacy, instructor, Escola Tecnica de Aviaco, Sao Paulo, Brazil; published by John Wiley & Sons, Inc., New York; 202 pages, 9 by 11⅝ inches, clothbound; available through MACHINE DESIGN, *$4.00 postpaid.*

Perspective illustration as a medium of engineering presentation gives to the workman a clear, direct pictorial and written description of a specific job to be executed. Author Treacy tells in detail how drawings should be made and shows their applications to industrial problems that have arisen in plants where such drawings are now in constant use. Incorporating the most practical and widely accepted standards, the book offers time-saving methods and devices for preparing such drawings—introduces the reader to "tricks of the trade" as well as to what kind of drawing is required and where.

The book is divided into two sections, the first of which, on the actual preparation of drawings, covers background information, drafting standards, shading techniques, reproduction aids, duplicating methods, photographic illustrations, linear perspective, and freehand drawing. A second section on general practical applications dwells upon the introduction of production illustration, general uses, departmental organization, reference illustrations, perspective engineering drawings, manufacturing illustrations, and a variety of miscellaneous industrial applications.

Treatment of this relatively new subject is concise and clear, and bulky discussions are supplanted by a wealth of excellent, appropriate illustrations. Though the material is drawn mainly from work in the aircraft industry, it is there that graphics or production illustrations have reached the highest form of development and methods presented are applicable to almost any machine or type of manufacture.

□ □ □

The New Plastics

By Herbert R. Simonds, consulting engineer, M. H. Bigelow, Major, CWS, U. S. Army and Joseph V. Sherman, economist; published by D. Van Nostrand Company Inc., New York; 311 pages, 5½ by 8½ inches, clothbound; available through MACHINE DESIGN, *$4.50 postpaid.*

To bring the designer up-to-the-minute on his knowledge of plastics materials, the authors of this book review the history of the achievements in plastics up to 1940 and then dwell in detail on developments since then. The new processes and applications which have appeared in profusion since 1940—including synthetic rubbers, organic coatings, and adhesives—are brought together in a clear, comprehensive treatment covering composition, methods of manufacture, properties, and uses. Many interesting data concerning the new fibers, laminating materials and rubber-like plastics complete the thorough round-up of information presented.

Shortages of war have served to bring these materials sharply to the forefront both in the industrial and domestic fields. Many designers expect phenomenal things of plastics which in all aspects may not be forthcoming for some time. The authors stress the fact that in spite of the great strides which have been taken, the ideal plastic is still some distance away. Most important, therefore, is a well rounded knowledge of available plastics to make possible the wise choice of a material to suit the conditions imposed. This book will aid immeasurably in achieving this goal.

Material presented not only covers those recent plastics which have already reached tonnage production, but also the newest ones which are still in the laboratory stage. Chemical diagrams of some of the more important new plastics are included in an Appendix at the end of the book. A chapter on present business facts and plastics trends is of special interest in appraising accurately the postwar outlook for applications and improvements in these synthetics.

□ □ □

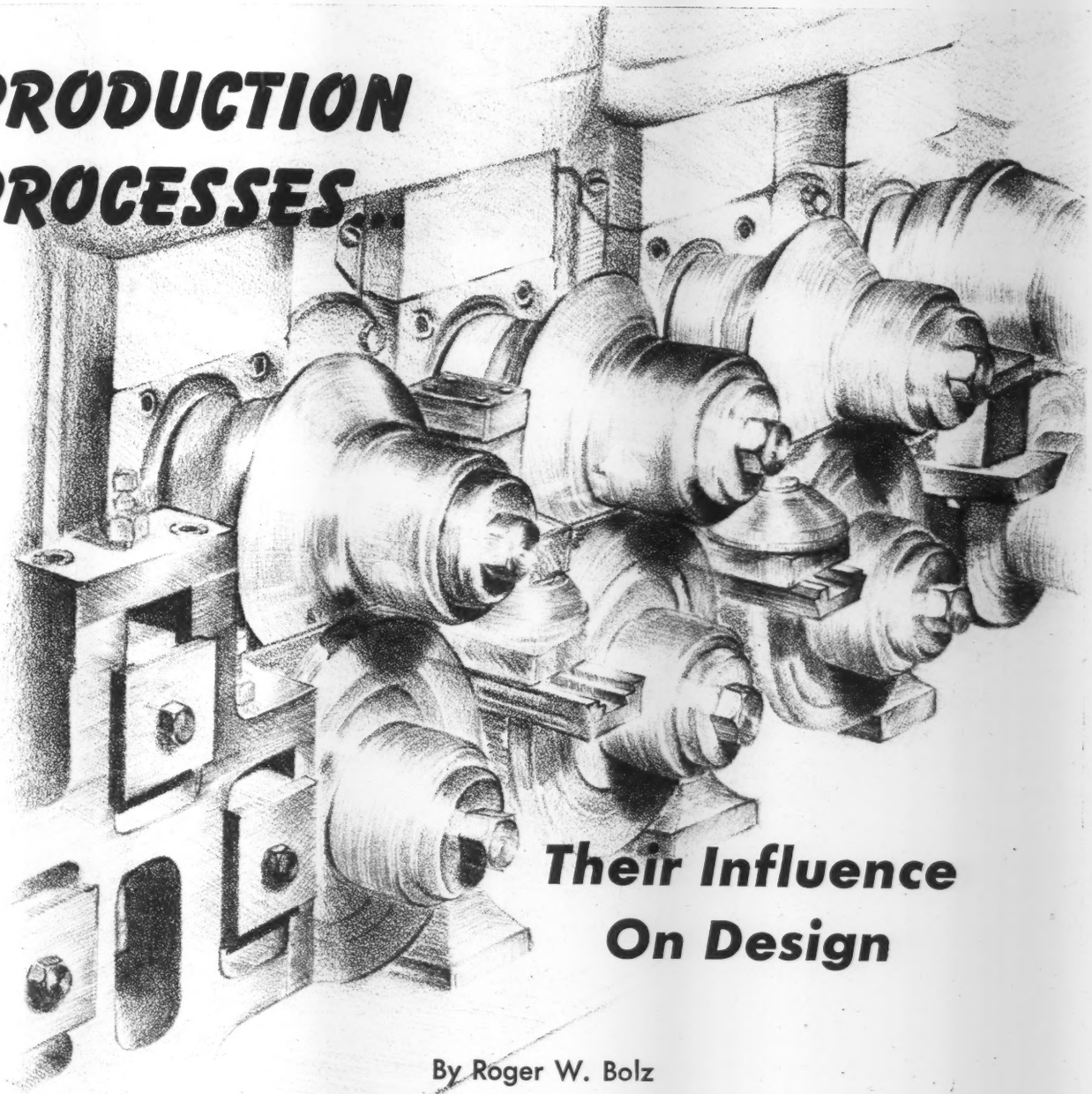
Instruments and Process Control

Published by The New York State Vocational and Practical Arts Association, Albany, New York; 233 pages, 8¼ by 10¾ inches, paper covers with plastic ring binding; available through Delmar Publishers, Inc., 49 Sheridan Ave., Albany 6, New York, $2.75 postpaid.

This interesting monograph on control of industrial processing was developed by R. E. Clarridge, J. S. Detwiler, G. E. Heller, and R. N. Pond of the Taylor Instrument Companies, Rochester, New York, in collaboration with B. C. Delahooke of the Curriculum Laboratory at Cornell University, Ithaca, New York. Work of preparing the material for publication was done by the various members of the Curriculum Laboratory staff.

Inasmuch as the machine designer originates much of the basic mechanical processing equipment to be controlled, working familiarity with all the outstanding control methods and instruments can be of considerable assistance. If such familiarity is desired, this book will aid immeasurably in achieving it. In addition, the great variety of typical and specialized industrial control applications discussed should prove a help in improving old or developing new designs.

PRODUCTION PROCESSES...



Their Influence On Design

By Roger W. Bolz

Associate Editor, Machine Design

Part X—Roll Forming

COLD ROLL forming parallels somewhat the stamping and drawing processes in its effects on the design of mass-produced machines. Early fields for the use of cold roll-formed shapes have broadened during the war years to include even a substantial portion of present-day aircraft parts. Probably the first volume use of roll-formed parts for machines began with the rapidly expanding automotive industry in the early 20's and has increased to the point where its outstanding versatility places it among the foremost mass-production methods to be considered by the designer of machines.

Aside from the decorative, trim, furnishing, architectural, and similar uses too

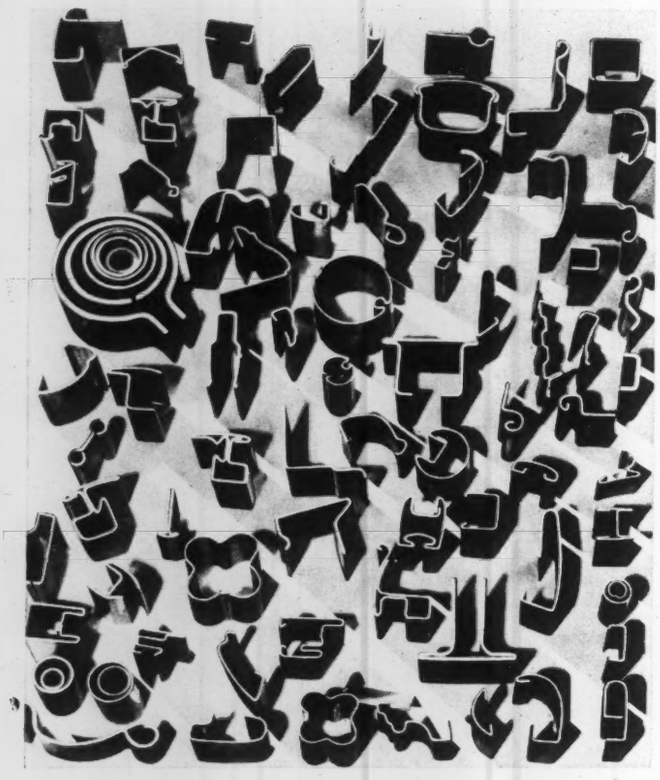


Fig. 1—Above—A group of sample cross sections showing the wide range of shapes which have been produced

numerous to mention, the uniformity, adaptabilty to assembly by modern welding methods, fine finish, low cost, etc., of roll-formed shapes have projected their use into the vast field of basic structural parts. Designers of automotive, farm, railroad, and aircraft equipment are rapidly taking advantage of the increased strength and decreased dead weight afforded by sections roll formed from alloy steel sheet. The rigid requirements of design, weight, strength, finish, and cost are met by taking the flat rolled steel—hot or cold-rolled—produced by the continuous mill in coils, slitting it into the necessary widths by multiple-gang slitters, and then cold-roll forming these coiled strips into the desired sections, *Fig.* 1.

Numerous machines are available for roll forming sheet materials, having from a few roll stations to as many as twenty depending upon the job, *Fig.* 2. Individual rolls on all stations are removable and only the number of pairs necessary for producing a particular section are used. As a strip passes through the machine each pair of rolls produces a partial change in the cross section, consequently the number of rolls required depends upon the intricacy or general nature of the section. A simple angle or channel section can usually be formed in three or four pairs of rolls, the more difficult sections frequently require ten or more.

Two basic styles of cold roll forming machines are available. One type has overhung roll shafts, both bearings of which are mounted within the drive housing, and the

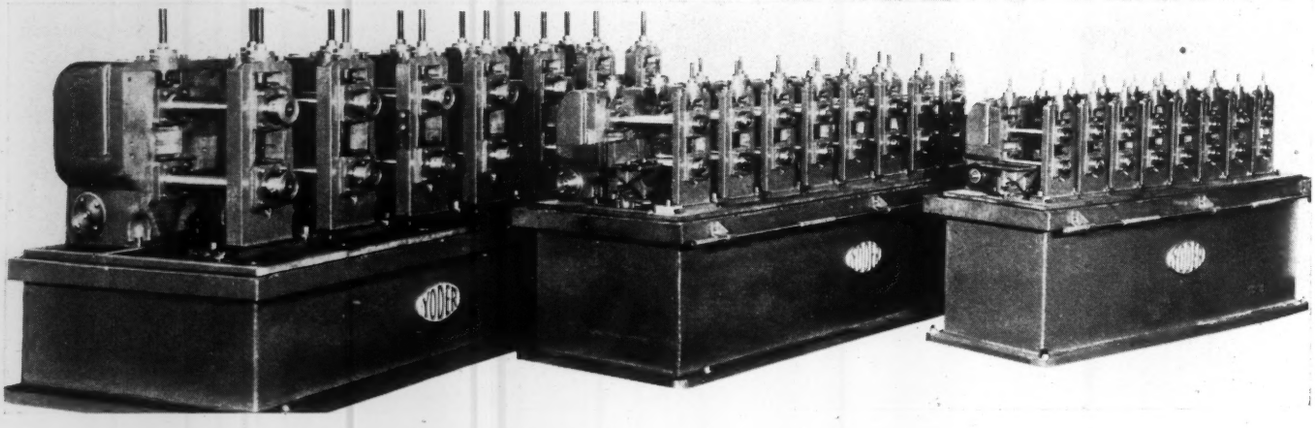
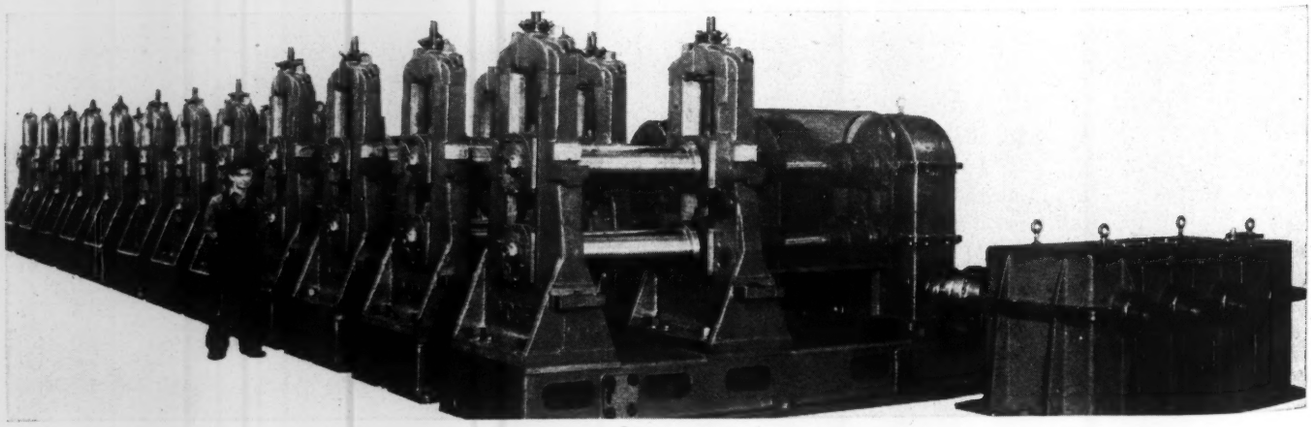


Fig. 2—Above—Three sizes of standard forming mills with stock capacities of 0.063, 0.094 and 0.125-inch thickness and widths of 6.5, 12 and 14 inches respectively

Fig. 3—Below—Rear view of a mill that will cold form shapes from plate up to 0.500-inch. Roll Spacings on such mills preclude production of light sections



second type, *Fig.* 2, has a double housing with inboard shafts. The overhung or outboard shaft machine can, in many cases, be set up for production in the shortest possible time. However, on long production runs, setup time has little significance in the overall costs. The fundamental difference, therefore, is not in setup, tooling, or function but rather in rigidity, versatility and capacity and these three factors determine the usefulness and efficiency of the one type over the other.

Where extremely light or narrow width sections are required, the overhung shaft type machine is entirely satisfactory. On the other hand, if versatility is necessary or sections contemplated for future production would tax the maximum capacity, inboard shafts are desirable to maintain accuracy and economy.

Unusual Versatility

Sections can be roll formed cold from almost any metal that can be stamped or drawn. Gage thickness of materials successfully handled to date ranges from 0.003 to 0.750-inch. A mill that will form structural and special shapes from sheet and plate up to ½-inch in thickness is shown in *Fig.* 3. Although the rolls on such a machine can be adjusted to accommodate this wide range of material thicknesses, *Fig.* 4, the indication is primarily one of versatility and adjustability. One set of rolls for any forming mill is, of course, not recommended for economical production over such a wide range of sizes inasmuch as a mill for roll forming ½-inch plate would be far too cumbersome and costly to operate for forming lightweight and smaller sections.

Early mills produced sections at a rate somewhere between 25 and 30 feet per minute. However, improvements and demand brought this speed up to around 75 feet per minute in the 20's. Today, most mills produce at around 100 feet per minute although some have been operated at speeds as high as 300 feet per minute. Rolling at a rate of 100 feet per minute, mills equipped with automatic flying cutoff equipment have an average output in production of 80 feet per working minute or 4800 feet per hour and thus a single machine will produce more than 10,000,000 feet per year.

Maximum economy in production, therefore, is dependent upon large quantity. Versatility is a necessity in most cases and one machine with five or more sets of tooling can accommodate short runs of 50,000 to 100,000 feet per year

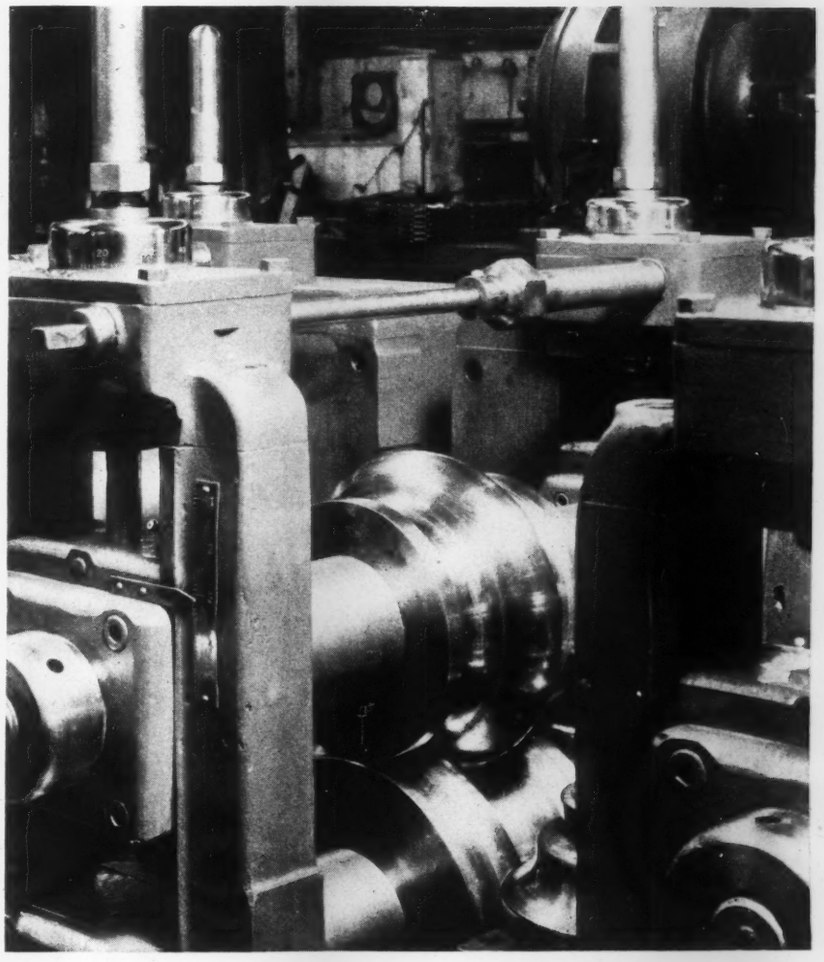
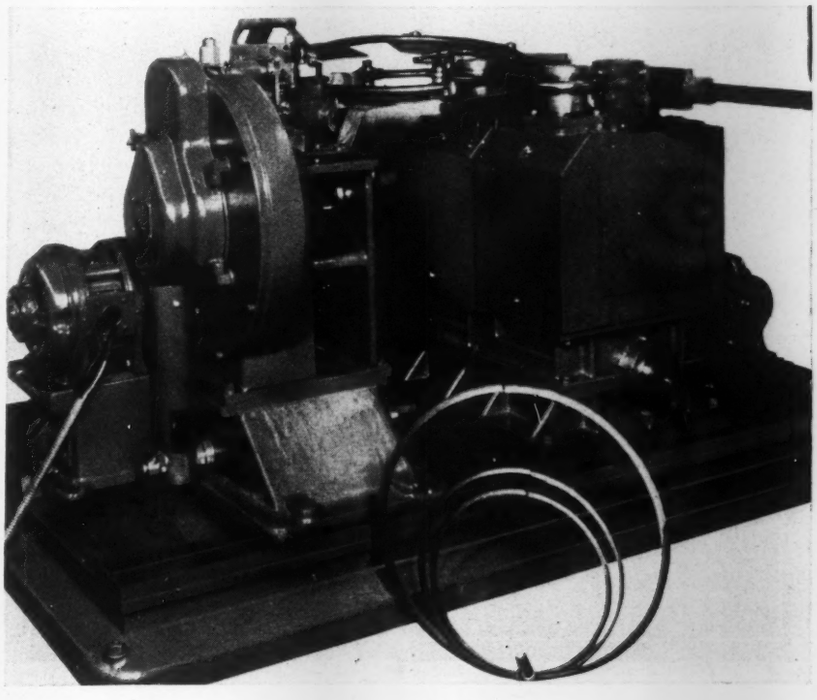


Fig. 4—Above—Detail view of cold roll forming heads showing parallel micrometer adjusting mechanism for upper roll spindle

Fig. 5—Below—An automatic roll forming, ring coiling and cutoff machine for producing wheel rims, bezels, hoops and other circular sections



in many cases. Tooling upkeep is not great and some three to four million feet of material can be produced on the average set of rolls before regrinding is necessary. Several regrindings can be made before rolls must be replaced.

Where vast quantities are to be produced, single-purpose mills are used to advantage. Automatic piercing or blanking machines as well as automatic cut-off saws or flying shears can be used. Use of automatic flying cutoffs has increased production almost 100 per cent over the older methods (running off the longest convenient length and then stopping the rolls while a swing or similar saw cuts off to length). Likewise the flying cutoff eliminates an extra press trimming operation.

A good example of automatic section forming is the production of continuous piano hinge. Stock is fed from a coil to an automatic machine which pierces or notches the strip continuously and accurately. The notched or pierced strip is then roll formed complete and passes through a flying shear where it is cut to exact length. Completely automatic, the setup produces at a rate of 60 feet per minute.

Welding can be used in conjunction with the roll forming operations to great advantage on single-purpose machines. The manufacture of electrically and atomic hydrogen welded tubing bears this out. Edges of a steel strip are prepared for welding and passed through the forming rolls directly to the welding unit. The welding bead is trimmed off as the tube leaves the welder and passes through a cooling tank to a sizing and straightening mill and an automatic cutoff in one continuous operation.

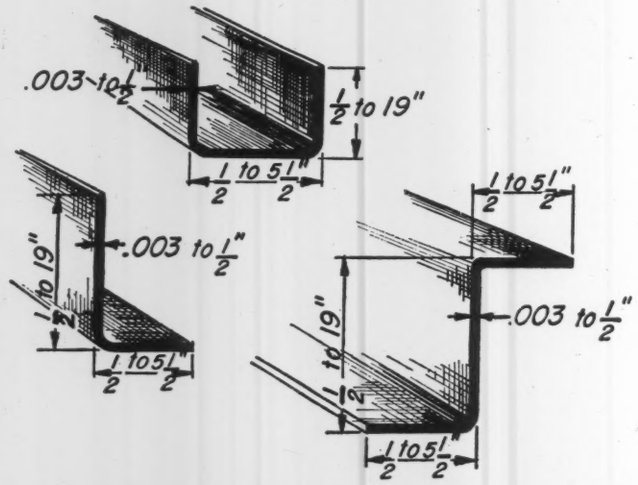


Fig. 6—Above—A number of simple sections produced on a mill equipped with adjustable rolls indicating the possible though not always economical range of sizes

Atomic hydrogen welding is used for stainless and high-alloy steels with production speeds from 10 to 90 inches per minute. Using 60-cycle or 180-cycle alternating current resistance welding on carbon steels, speeds up to 150 *feet* per minute have been attained.

Machines can be equipped with a coiling attachment at the exit end for the rolling of ring sections in various diameters for ventilators, instrument bezels, bicycle wheels, light rims, guards, furnace rims, etc., *Fig.* 5, thus eliminating an extra operation. Painting devices can also be used to advantage.

DESIGN: Although design variations in parts which lend themselves to this method of production are almost unlimited as exemplified by the shapes shown in *Fig.* 1, there are a few limitations which designers should consider in planning new parts. Sharp corners on shapes require sharp corners on the rolls thus shortening roll life. For better forming characteristics and maximum roll life, the ratio between the radii of bends and the gage of the material should be kept as large as possible.

Light Sections Best if Shallow

Shapes of thin material should be kept as shallow as possible so that roll diameters can be smaller and less expensive equipment necessary. The sections shown in *Fig.* 6 will give an excellent indication of the work that can be done in a machine equipped with adjustable rolls. This wide range of sizes, however, would not be considered for economical mass production on only one machine.

Short pieces of material (lengths less than twice the center distance between spindles) do not feed through a machine conveniently. Thus, parts adapted to continuous forming from coil stock strip with automatic cutoff (also blanking where necessary) are most economical.

An all-round understanding of the factors which enter into the design of parts to be roll formed must of necessity include some details on the design of the rolls used. Good judgment is an important factor contributing to successful part and roll design. The process is not unlike that found in progressive die forming. If a shape has four or five breaks or bends across its width, it would be logical to distribute the work of bending first of all singly and at that only in increments of 20 to 25 degrees at a time. After examining the sequence of working, *Fig.* 7, some of the steps can be combined so that the number of operations or roll stations are at a bare minimum.

By slowly unfolding or unforming a specified shape in these stages, the general design of each roll pass is determined, *Fig.* 8. The rule of restricting the work of bending to 20 to 25 degrees per roll pass is a conservative figure

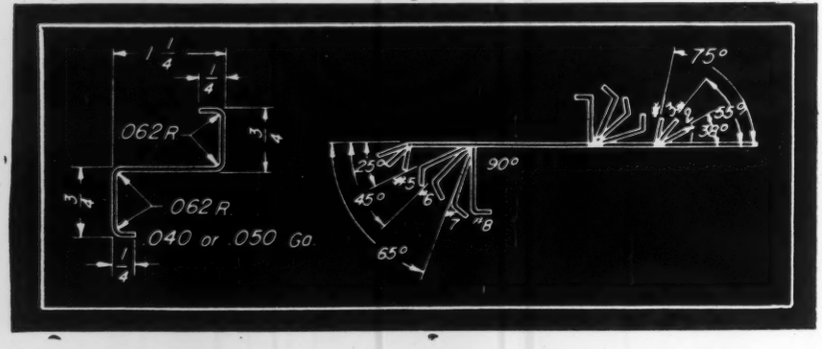


Fig. 7—Left—A Z-section layout and breakdown of the forming angles. The 65-degree flange and 75-degree leg bends are used primarily to allow clearance for rolling the leg corner radius

and will usually work successfully for a great many varying hardnesses and types of metals, except special aluminum alloys and stainless steel, to produce a section with minimum twist or distortion. Work of bending at the first pair of rolls may run to angles as great as 45 degrees but that at the remaining stations is usually less. As a section progresses through a machine, the amount of work done at successive stations is decreased to achieve accuracy.

This possible satisfactory angle of bending must be modified somewhat by the forming angle — that compound angle described by the edge of the sheet as it passes from one roll station to the next—which is limited by experience to such an amount that the stretch induced in the edge of the strip does not exceed the elastic limit of the material being rolled. Thus the depth of a section may modify the maximum bending angle and actually determine the number of roll stations required. The total rise of the edge of a section through the mill, or in other words, the actual depth of the part which becomes the leg of a right triangle in conjunction with the horizontal spacing of the spindles, determines the approximate number of roll passes.

Bow and Twist Neutralized

Bending or twisting which often results during rolling from slight inaccuracies or variations in the structure or hardness of the strip material is usually overcome by means of a straightener provided at the exit from the rolls, *Fig.* 10. Bow or twist resulting from internal stresses in the section which are not properly balanced about the neutral axis can sometimes be neutralized by preforming the strip in the first pair of rolls. This preform action sets up stresses opposed to those which produce the twist by creating a stretching effect on both sides of the neutral axis, *Fig.* 11. This method also helps eliminate undesirable springback in the harder metals.

MATERIALS: Practically any material that can be formed or bent by any other process can be roll formed, and frequently it is possible to roll form a section so intricate that it could not be produced economically by any other continuous process. The harder temper materials have a tendency to crack under severe high-speed forming, consequently it is desirable as well as economical to use the more ductile or formable materials available. The extremely soft materials such as aluminum alloy, copper, brass, and zinc, on the other hand, require the highest accuracy in roll tooling to obviate waviness on the rolled surfaces.

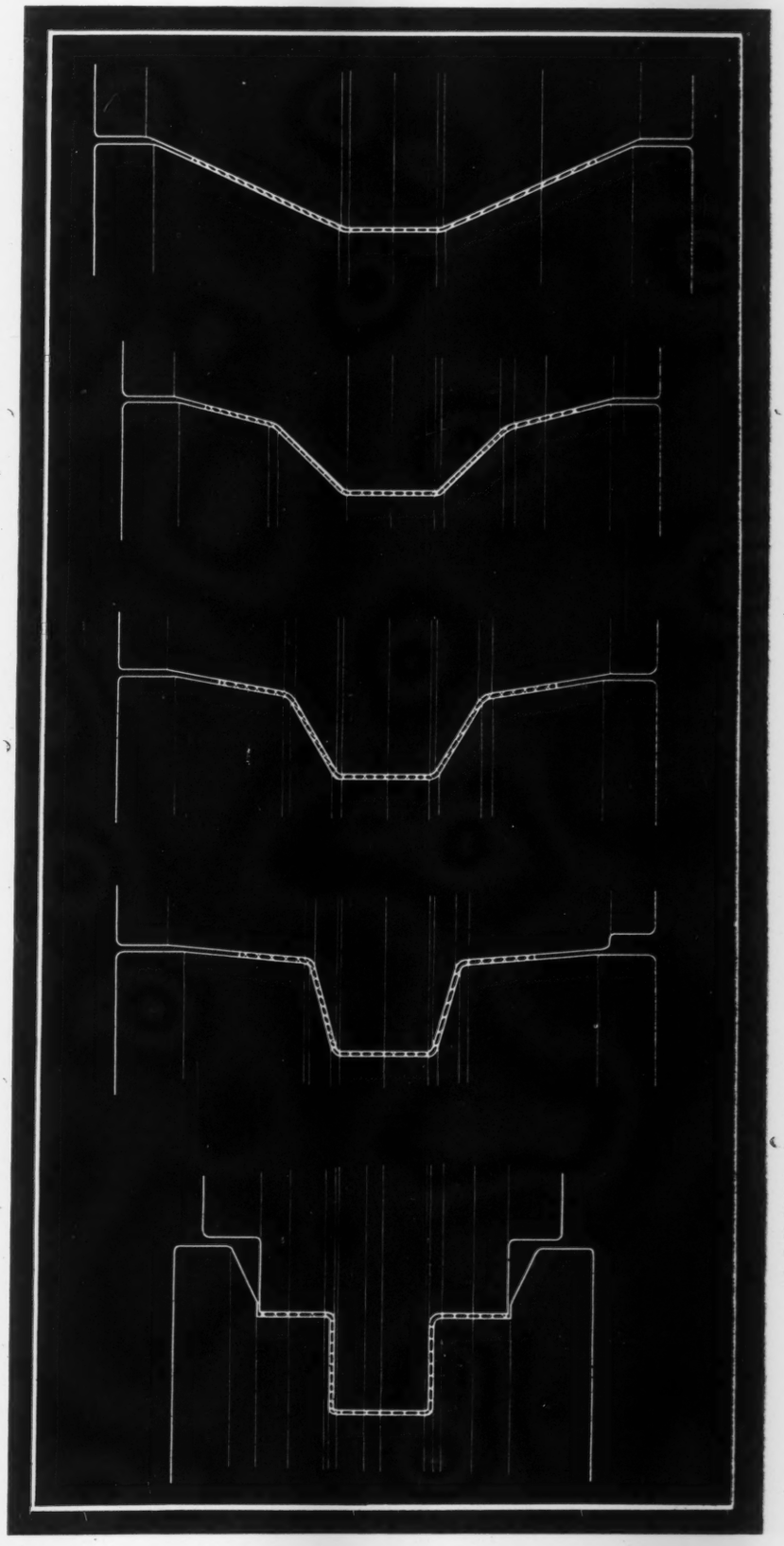


Fig. 8—Sequence of roll stations showing flanged U-shape taking form progressing from the outside inward

A wide variety of clad metals such as the several aluminum alloy

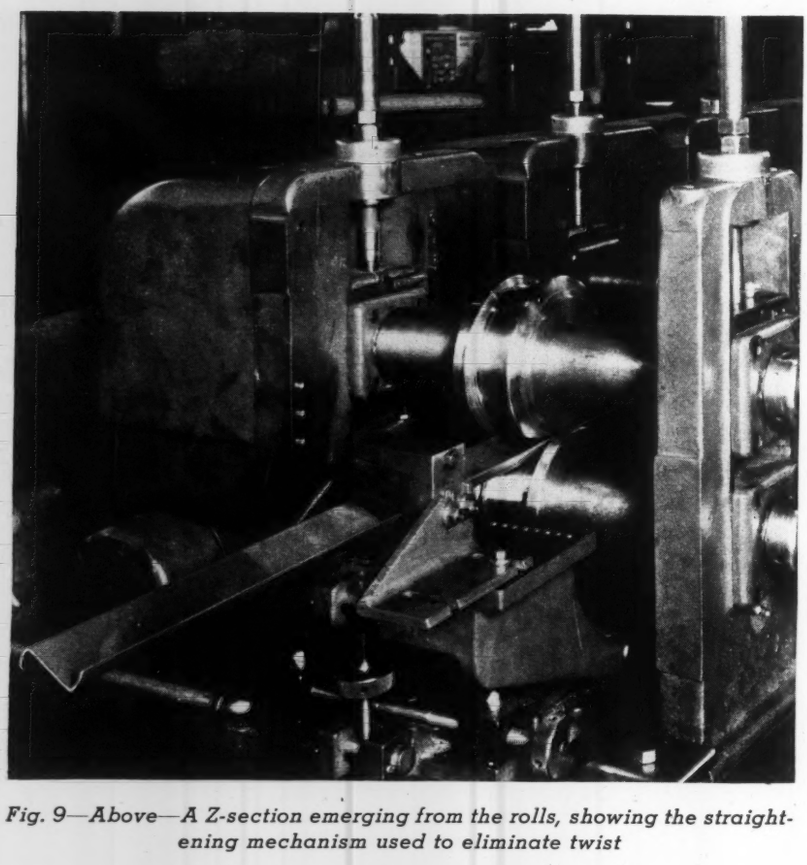


Fig. 9—Above—A Z-section emerging from the rolls, showing the straightening mechanism used to eliminate twist

Fig. 10—Below—By preforming the strip at the first pair of rolls, right below, stretching is produced on both sides of the neutral axis of a section to avoid twist, bow and springback, left. Angle "b" is made less than 90 degrees, the exact amount depending upon the material characteristics

combinations can be handled successfully as well as the magnesium-clad alloys. Stainless and high alloy steels having a tensile strength of from 180,000 to 200,000 psi can be cold roll formed in high-speed production and, as previously noted, can be atomic-hydrogen welded during the forming process.

TOLERANCES: Uniformity or accuracy in the size of sections produced naturally is limited by the uniformity of the sheet material used. Cold rolled sheet material of course has the best surface finish and rolling characteristics as well as closest gage accuracy.

Runout Affects Accuracy

Width of a simple channel section such as that shown in *Fig.* 6 can be held to plus or minus 0.005-inch or less in continuous production. Runout in machine spindles, bearings and rolls has a considerable effect on the finished accuracy of rolled sections. Without question, the less the total of these runouts the better the forming characteristics. In forming the heavier gages from about 14 gage and up, two or three thousandths total runout will have little effect on the accuracy of the sections produced. However, on lighter gages, a few thousandths runout would amount to about 20 to 50 per cent of the metal thickness and cause waviness in the final part. This is particularly true of the softer metals, consequently maximum allowable total runout is limited to 0.0008-inch for gages around 0.005-inch, 0.0013-inch for gages around 0.015-inch, 0.0018-inch for gages around 0.031-inch, 0.0024-inch for gages around 0.040-inch, and 0.0026-inch for gages around 0.002-inch.

Finished sections cut to length by automatic flying cutoffs can be held within normal commercial limits, obviating further trimming for interchangeability. On these cutoffs, the trips—either mechanical or electrical—are mounted on the runout table and are adjustable so that the length of cut can be set to repeat within plus or minus 0.015-inch. Generally, tolerances on cut lengths run about plus or minus 0.031-inch and, depending on the type of trip used and the length and cross section of the shape rolled, may vary from plus or minus 0.015-inch to plus or minus 0.062-inch.

Collaboration of the following companies in the preparation of this article is acknowledged with appreciation:

Mitchell Division, United Specialties Co. (*Fig.* 10) ..... Philadelphia
Tishken Products ..... Detroit
The Yoder Co. (*Figs.* 1, 2, 3, 4, 5, 6, 7, 8, and 9) ..... Cleveland

Design Opportunities in Fastener Assemblies

By W. M. Hanneman
Chief Engineer
Shakeproof Products, Illinois Tool Works, Chicago

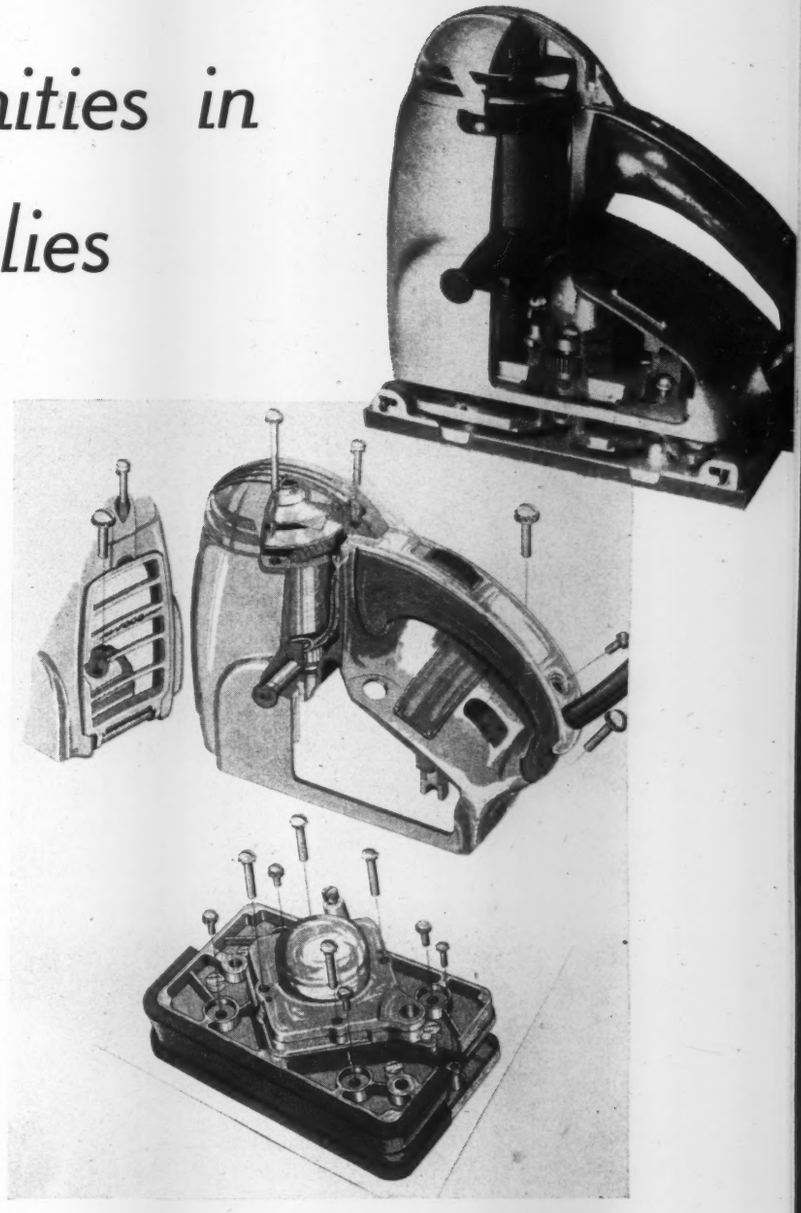


Fig. 1—Unit lock washer and screw fasteners facilitate assembly and re-assembly of portable sander

OF THE many types of fasteners available to the designer, the screw and lock washer undoubtedly is the best known and most universally employed. Use of a lock washer under a screw head stands as an accepted method for securing the screw against loosening.

In the use of screws and lock washers in manufacturing industries, common procedure has been to place the lock washer on the screw, to insert the screw in the hole and to drive it home. Some time ago simplification of this procedure was achieved by combining the screw and lock washer into a single fastening unit, eliminating the necessity of combining the two components as an extra operation. This product has become so firmly established that about 17 screw manufacturers now produce it.

Assembly of a screw and lock washer is made possible by the fact that the diameter over the thread of a rolled-thread screw is greater than the diameter of the blank from which the screw is made. Diameter of the unthreaded screw blank is approximately the same as the pitch diameter of the finished screw. Upon this blank is placed a lock washer with hole diameter slightly larger than the blank. During thread-rolling, the screw diameter increases and becomes greater than the hole diameter of the washer. The washer, therefore, is trapped between the head and threads of the screw.

Screw and washer assemblies of this type, wherein the washers are held beneath the screw heads and are free to rotate, are called "sems". This word, coined several years ago, is used generally in the screw trade to designate these fastener units.

Screw and washer assembly units have engineering values aside from the labor-saving feature. On a tooth-type lock washer, the minimum rim and length of tooth is limited. Too narrow a rim would reduce the strength and too short a tooth would reduce locking efficiency. Lock washers used on sems, having a hole smaller than the diameter of the screw, offer maximum efficiency because of the wide tooth section in contact with the screw head.

From the point of view of application in design, the fact that sems utilize lock washers of small diameter offers another advantage. In cases where space is limited, this feature is useful. Examples may be found in many types of small machines.

When it is necessary to assemble small pieces in difficult places, such as are found in electrical devices and appliances, the workman requires more than ordinary dexterity. To put a short screw through a loose lock washer and a machine part and start it correctly into a tapped hole in an awkward location sometimes is almost impossible. Specification of the combined screw and lock washer in such instances may simplify the operation materially.

Some types of machines must be dis-assembled and re-assembled from time to time for maintenance and replacement of working parts. The manufacturer, by using sems in the original assembly, can insure against subsequent re-assembly without the necessary lock washers.

During the war period, inspectors often were required to check each screw to ascertain that the washers were not left off intentionally or otherwise. Inspection can be facilitated, therefore, when screw and washer assemblies are used, because each screw is assured a companion lock washer. Piecework operators looking for short cuts cannot omit the lock washers.

In the electric portable sander shown in *Fig.* 1, use is

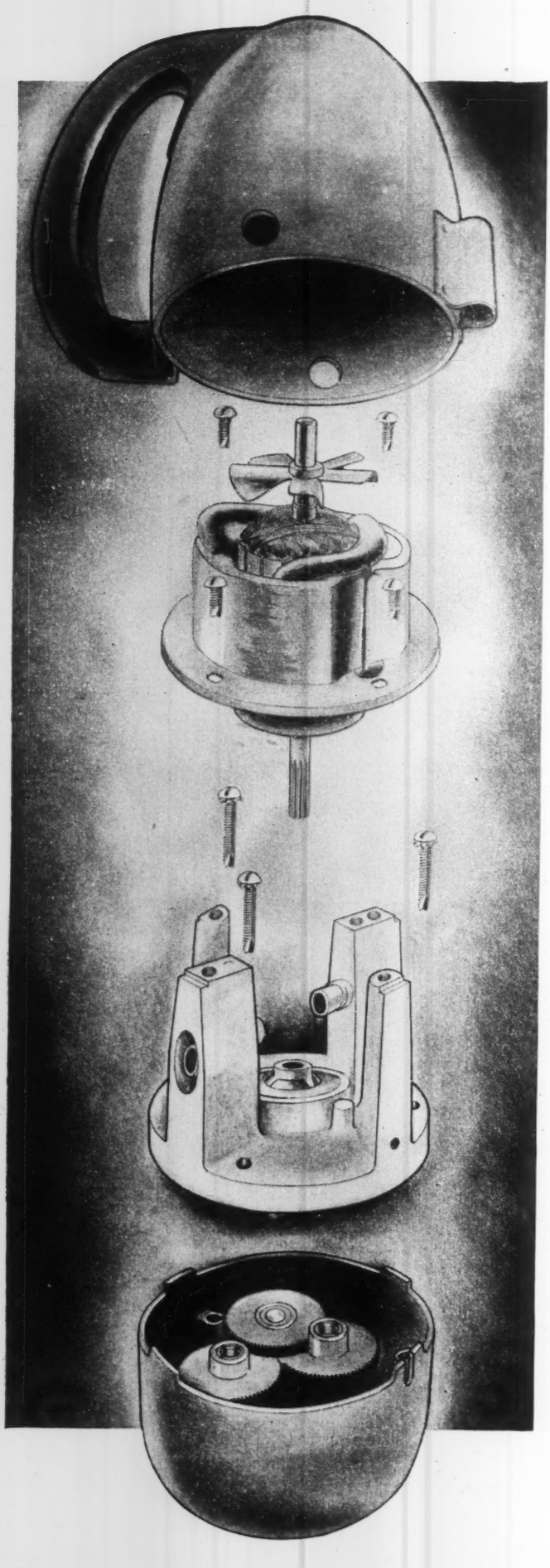


Fig. 2—Left—Seven self-tapping screws, three being pre-assembled with lock washers, are used in this food mixer

made of 16 sems of various sizes. This sander, developed by the Sterling Tool Products Co., Chicago, has a flexible sanding pad which oscillates at a speed of 5000 cycles per minute. Obviously, a high-speed machine of this type must have fastenings which will not loosen in service.

A similar use of sems is shown in *Fig.* 2. In this electric food mixer, manufactured by the Dormeyer Corp., Chicago, three thread-cutting sems hold the motor frame to the die-cast transmission housing. Four thread-cutting screws fasten the two-piece die-cast motor frame, but these do not require lock washers. *Fig.* 3 shows the manner in which the door hinge on Plymouth automobiles is fastened to the body by means of pre-assembled screws and lock washers.

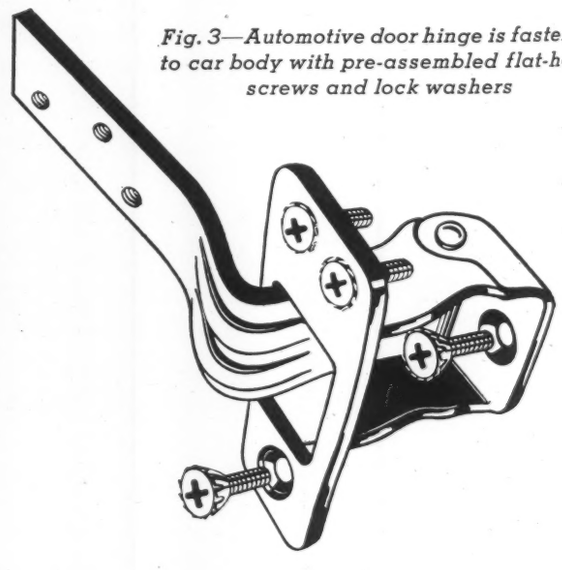
Screw and lock washer assemblies have been standardized for all standard machine screws from No. 2 (0.066-inch) to ⅜-inch diameter. Standard external tooth, internal tooth, and helical spring washers have been established for each size of screw. Flat and oval-head screws, however, have standard external tooth washers only.

With the introduction of sems, many machine designers and engineers began to suggest that the combination idea be adapted to applications in which special types of lock washers were being used. As a result, many sems embodying various special washers are being made today. External-internal, dome and dished designs of washers are used in many places. Special lock washers of oversize outside diameters also are used extensively.

From an operating standpoint, use of screw and washer assembly units has advantages. Substitution of a single item for two simplifies procurement by the purchasing department. Fewer storage bins are required, facilitating inventory control and precluding unbalance between screws and lock washers.

From the standpoint of the designer, perhaps the most attractive field for the application of sems lies in the possibility of combining in a single assembly not only the screw and a special lock washer, but also one or more additional elements which, under the present pressure for cost reduction in mass production, can be incorporated into the fastening assembly advantageously.

Fig. 3—Automotive door hinge is fastened to car body with pre-assembled flat-head screws and lock washers



MACHINE DESIGN'S

MATERIALS WORK SHEET

FILING NUMBER
15.00

Nickel

WROUGHT AND CAST

ASTM SPEC. NOS.:

B160-41T (Hot-rolled rods, cold-drawn rods, forgings)
B161-41T (Seamless tubing)
B162-41T (Cold-rolled sheet, cold-rolled strip, hot-rolled plate)
B163-41T (Condenser tubes)

AVAILABLE IN:

Cold-rolled sheet and strip, cold-drawn rods and bars, seamless tube and pipe, welded tube and pipe, forged billets and shapes, hot-rolled plate and sheet, hot-rolled rods and bars, hot and cold-rolled angles, and castings

ANALYSES: *(nominal)*

	Ni*	Cu	Fe	Mn	Si	C	S
Wrought	99.4	0.1	0.15	0.2	0.05	0.1	0.005
Cast	97.0	0.3	0.25	0.5	1.5	0.5	0.015

*Including cobalt.

PROPERTIES

TENSILE STRENGTH (*psi*)

Cold-drawn wire, annealed	65 -85,000
No. 1 temper	90-105,000
regular temper	105-140,000
spring temper	135-165,000
Cold-drawn rod and bar, annealed	65 -85,000
as drawn	80-115,000
Hot-rolled rod and bar	65 -80,000
Forged rod and bar	70-105,000
Hot-rolled plate, annealed	65 -80,000
as rolled	70-100,000
Standard cold-rolled sheet	60 -80,000
Standard cold-rolled sheet and strip, annealed	60 -80,000
Standard cold-rolled strip, full hard	100-130,000
Standard cold-rolled sheet, full hard	100-115,000
Cold-drawn tubing, annealed	60 -80,000
as drawn	80 -95,000
Castings	45 -60,000

YIELD STRENGTH (*0.2% offset, psi*)

Cold-drawn wire, annealed	15 -30,000
Cold-drawn rod and bar, annealed	20 -30,000
as drawn	60 -90,000
Hot-rolled rod and bar	20 -35,000
Forged rod and bar	20 -80,000
Hot-rolled plate, annealed	15 -30,000
as rolled	20 -75,000
Standard cold-rolled sheet	15 -30,000
Standard cold-rolled sheet and strip, annealed	15 -45,000
Standard cold-rolled strip, full hard	70-115,000
Standard cold-rolled sheet, full hard	70-105,000
Cold-drawn tubing, annealed	15 -25,000
as drawn	50 -80,000
Castings	20 -30,000

ELONGATION IN 2 INCHES (*per cent*)

Cold-drawn wire, annealed	50-30
No. 1 temper	20 -5
regular temper	15 -4
spring temper	10 -2
Cold-drawn rod and bar, annealed	50-30
as drawn	35-15
Hot-rolled rod and bar	60-35
Forged rod and bar	40-20
Hot-rolled plate, annealed	50-35
as rolled	45-30
Standard cold-rolled sheet	45-35
Standard cold-rolled sheet and strip, annealed	45-35
Standard cold-rolled strip, full hard	15 -2
Standard cold-rolled sheet, full hard	15 -2
Cold-drawn tubing, annealed	45-35
as drawn	35-15
Castings	30-15

PHYSICAL CONSTANTS

Specific Gravity	8.89
Density (lb/cu in.)	0.321
Melting Point (deg F)	2615-2635
(deg C)	1435-1445
Specific Heat at 80 to 212 F (27 to 100 C)	0.130
Coefficient of Thermal Expansion	
(68 to 212 F, per deg F)	0.0000072
(25 to 100 C, per deg C)	0.0000130
Thermal Conductivity	
at 80 to 212 F (btu/sq ft/hr/deg F/in.)	420
at 27 to 100 C (cal/sq cm/sec/deg C/cm)	0.145
Electrical Resistivity	
at 32 F (ohms/circ mil ft)	57
at 0 C (microhms/cm³)	9.5
Temperature Coefficient of Electrical Resistivity	
(per deg F) 68 to 212 F	0.0022-0.0028
(per deg C) 20 to 100 C	0.0043-0.0050
Modulus of Elasticity, in tension (psi)	30,000,000
in torsion (psi)	11,000,000
Poisson's Ratio	0.31

MACHINE DESIGN is pleased to acknowledge the collaboration of The International Nickel Company Inc. in this presentation.

BRINELL HARDNESS
(3000 *kg*)

Cold-drawn rod and bar, annealed	100-150
as drawn	140-230
Hot-rolled rod and bar	100-140
Forged rod and bar	110-200
Hot-rolled plate, annealed	100-140
as rolled	100-200
Castings	80-125

CHARPY IMPACT VALUES AT SUBZERO TEMPERATURES
(*ft-lb*)

Test Temp. (F)	Hot Rolled	Cold Drawn	Annealed
Room	195	185	216
−112	236	205	235
−310	227	210	234

SHORT-TIME ELEVATED-TEMPERATURE PROPERTIES HOT-ROLLED NICKEL
(*strength data to nearest* 1000 *psi, elongation data to nearest* 1 *per cent*)

Test Temperature (F)	Tensile Strength (psi)	Yield Strength 0.2% offset (psi)	Elong. in 2 in. (%)
Room	73,000	24,000	49
200	77,000	21,000	52
300	76,000	21,000	46
400	79,000	23,000	49
500	76,000	24,000	48
600	83,000	22,000	50
700	80,000	22,000	50
800	76,000	21,000	52
900	65,000	20,000	51
1000	46,000	17,000	55
1100	37,000	15,000	55
1200	34,000	15,000	57
1300	32,000	14,000	59
1400	27,000	12,000	61
1500	25,000	.....	65
1600	16,000	.....	76
1700	12,000	.....	84
1800	8,000	.....	91

Specimens held ½-hr at temperature before testing. Rate of pulling: 0.0016-in. per min. to yield strength; then 0.0026-in. per min. until fracture.

TEMPERS AND HARDNESS VALUES COLD-ROLLED SHEET AND STRIP

Temper	Rockwell B	Shore
Dead Soft	under 56	under 13
Soft	56-64	13-14
Skin Hard	65-70	15-16
Quarter Hard	71-79	17-20
Half Hard	80-85	21-25
Three-Quarter Hard	86-91	26-29
Hard	92-95	30-35
Full Hard*	over 95	over 35

* Available in strip only.
Note: Soft temper sheet includes both soft and skin-hard ranges of hardness unless specified as to maximum hardness.

CHARACTERISTICS

Wrought nickel, as used in industry, is the commercially pure metal. It combines excellent mechanical properties with corrosion resistance that is good generally and outstanding under many conditions of exposure. It can be fabricated by all commercial processes and is not affected adversely by cold working, welding, casting or heating. Its mechanical properties are similar to those of mild steel. It retains its strength to an excellent degree at high temperatures, and its ductility, toughness and strength at subzero temperatures. Aside from its corrosion resistance and strength, nickel has the following noteworthy characteristics: Good thermal conductivity, good electrical conductivity, high modulus of elasticity, and thermal expansion nearly the same as that of steel. The elastic and ultimate strengths of nickel cover wide ranges depending on its cold or hot-worked condition. Strength range is above that of the common types of brasses, bronzes and nickel silvers, and approaches that of some alloy steels. Strength and hardness of nickel can be increased by cold working, but not by heat treating.

APPLICATIONS

Nickel is used extensively throughout the food processing, chemicals, pharmaceuticals, and textile processing industries for storage tanks, evaporators, jacketed kettles, heating coils, etc. Steam coils of seamless nickel tubing are used regularly in the manufacture of carbon tetrachloride. Other typical applications are: Expansion joints, autoclaves, metal elements of electronic vacuum tubes, oil well strainers, fittings in the chemical processing industries, brine tanks, wine bottling tanks, beer storage tanks, trays used in baking china and in brazing high-speed cemented carbide tools to steel shanks, chlorinators for aniline, paraffin, etc., and condensers and heat exchangers for many processes. Because nickel is strongly magnetic at room temperature (it becomes nonmagnetic at about 650 F), it is useful for mechanical parts that must be operated by magnetic attraction and at the same time be corrosion resistant. The low residual magnetism of the material contributes greatly to its usefulness for such parts. Nickel electrical contacts stand up well under arcing.

FABRICATION

MACHINABILITY:

Nickel should be ordered in the form of cold-drawn rods or bars in the "as-drawn and normalized" temper to obtain the best grade for machining. However, if the rods are to be subjected to cold-forming operations, cold-drawn No. 1 temper material should be specified for sizes to ⅜-inch inclusive and, above ⅜-inch cold-drawn annealed material is recommended, even though these softer tempers may be slightly less desirable for machining. Because of the toughness of nickel, cutting speeds are slightly slower and feeds lighter than those used for mild steel. Tools should be either high-speed steel, a cast nonferrous cutting material or cemented carbide. Tool relief angles should be kept to a minimum so as to afford sufficient support for the cutting edge and enough bulk of tool material to carry away the heat generated at the edge. Rake angles should be large enough to reduce chip pressure and consequent frictional heat. Back rake on the order of 12 degrees and side rake of 15 degrees is satisfactory for general work. A good grade of water soluble oil or sulfurized oil should be supplied to cutting edges in copious quantities.

Nickel is machined with high-speed steel tools at 50 to 70 fpm; with cast nonferrous tools at 80 to 100 fpm; and with cemented carbide tools at 200 to 350 fpm. For general lathe work feeds of 0.012 to 0.018-inch per revolution are satisfactory.

Whenever specifying hot-rolled rounds, flats, squares and hexagons for machining, allowance should be made in overall size to insure that the finished size will have properly cleaned surfaces. Recommended allowances are here listed:

Allowances for Finish Machining of Hot-Rolled Products

Size (inches)	Allowance for Rounds	Allowance for Flats, Squares and Hexagons
Up to 7/8 (incl.)	1/8-in. on diam	1/8-in. on each side
1 to 1 7/8 (incl.)	1/8-in. on diam	3/16-in. on each side
2 to 2 7/8 (incl.)	1/8-in. on diam	3/16-in. on each side
3 to 4 1/2 (incl.)	3/16-in. on diam	3/16-in. on each side

DRILLING:

Standard high-speed twist drills as furnished by drill manufacturers are satisfactory for general-purpose drilling. The web at the drill point should be thinned to avoid excessive drilling pressure. Drills with polished flutes are preferable and they should be reground as soon as they show signs of dulling. Heavy-duty, parallel-web drills are sturdier and will, in most instances, give better service than conventional standard web drills. In hand feeding, sufficient pressure should be applied to keep the cutting edge of the drill underneath the metal surface constantly. If the drill is permitted to dwell it will polish and harden the metal at the base of the hole. This will make it difficult to resume cutting and may result in breaking the drill when the cutting edge does dig in. A large amount of cutting oil should be flowed onto the cutting edge of the drill. For holes of average depth, soluble oil lubricant is suitable. Sulfurized oil is helpful although not necessary for deep drilling. It has been found beneficial to thin out sulfurized oil with kerosene when drilling small holes.

REAMING:

Spiral-fluted, high-speed steel reamers with narrow lands and well polished flutes generally are used and should be kept sharp at all times. To obviate the possibility of digging and chattering, ample lubrication with sulfurized mineral oil thinned with kerosene, or soluble oil and water is employed on all reaming operations. Recommended amounts of material to be removed by reaming in the various size holes are listed below:

Amount of Material to be Removed by Reaming

Hole Diam (inches)	Material To Be Removed
1/8 to 1/4	to 0.005-in. on diam
1/4 to 1/2	to 0.008-in. on diam
1/2 to 1	0.012-in. on diam
1 to 2	1/64 to 3/32-in. on diam

Reaming speeds should be about one-half that used for a corresponding size drill using a feed of three to four times that of the drill.

TAPPING:

Being extremely tough, this material requires a slightly larger tap drill for a given thread than is customarily considered standard. Specify a tap-drill size which will result in 75% depth of thread. Nickel, having high ductility, will flow into the roots of the tap threads, producing what for all practical purposes amounts to a full-depth thread. A suitable lubricant (sulfurized oils are best) is always used in tapping operations since without lubrication nickel has a tendency to gall on the tap. Nickel is tapped at 15 to 25 fpm.

SHEARING AND PERFORATING:

Shearing of nickel sheet and plate requires slightly more power than is needed for the shearing of soft steel having the same thickness.

Material having soft to skin-hard temper is preferred for perforating. Minimum hole diameter that can be punched on an economical production basis must be larger than the thickness of the sheet up to a thickness of approximately 5/32 to 3/16-inch. For heavier plate, the minimum diameter of the hole may be equal to the thickness of the sheet. Recommended minimum hole diameters for various sheet thicknesses are listed below and apply to soft and quarter-hard tempers:

Minimum Punched-Hole Diameters

Sheet Thickness (inches)	Min. Hole Diam (inches)
0.018 to 0.034	Sheet thickness x 1.5
0.037 to 0.070	Sheet thickness x 1.3
0.078 to 0.140	Sheet thickness x 1.2
5/32-inch and heavier	Sheet thickness x 1.0

In particularly favorable setups it is possible to punch holes smaller than the sizes listed. Die and punch clearances for light gage sheets are the same as for neat steel punching. For 1/4-inch and heavier plate, less clearance than for steel often is used to produce clean holes, free of burrs. A heavy, sulfur-base oil is used as a lubricant in punching and is thoroughly removed before the punched sheet is annealed or heated for any other purpose.

DEEP DRAWING:

Cold-rolled sheets and strips in soft temper and with fine to medium grain are most suitable for deep drawing. Nickel responds well to cold working and can be formed into any shape that can be produced from steel of deep-drawing quality. Very few commercial operations require changes or variations in die equipment designed originally for drawing steel or brass.

On a double-action press with pressure ring, a well-balanced series of reductions for light-gage cylindrical shells, with no "ironing" of the side walls, would be approximately 30 to 40 per cent in the first or cupping operation, and 15 to 25 per cent on redrawing operations. Single-action redraws without pressure rings rarely exceed 20 per cent for light gages; however, with very slight diameter reductions (less than 5 per cent), up to 30 per cent reduction in wall thickness can be obtained. Experience has shown that the depth of rectangular draws should be limited to from 2 to 4 times the corner radius.

For ordinary deep drawing of light-gage cylindrical shells, an overall die clearance equal to about 40 to 50 per cent of the thickness of the material is ample and not conducive to wrinkling. With heavy-gage sheets, an overall clearance equal to the gage of the stock generally is provided. Draw-ring and punch-nose radii for light-gage cylindrical shells usually range from 5 to 12 times the stock thickness. Corner-edge radius for a rectangular shell should be from 4 to 10 times the stock thickness. Because deep drawing cold-works the material, annealing may have to be resorted to between successive draws (see Annealing). Suitable lubricants are used on all deep-drawing operations, being thoroughly removed before annealing.

SPINNING:

Although nickel sheet and strip in the annealed condition is practically as ductile as softer metals such as copper, brass, aluminum and nickel silver, it is stronger and work-hardens faster. Thus more power is required to spin it and more frequent annealing is necessary. In general, roller-type tools are preferred because they create less friction than do the

solid-nose types. Nickel is spun at speeds from one-half to three-quarters of those used for the softer metals, and a heavy-bodied lubricant always is used.

SOFT SOLDERING:

Usefulness of soft soldering for joining nickel parts is limited to those applications where soft solder is not corroded readily. Soft solder inherently has low strength, and usually dependence for strength must be placed on mechanical joints, such as riveted, lock-seamed or spot-welded joints, with the solder acting only as a sealing medium. The process usually is limited to joints in sheet metal not more than 0.050 to 0.062-inch thick, because other processes yield stronger joints in these and heavier gages. The 50-50 and the 60-40 tin-lead solders are used most widely. Pure tin is justified only where corrosion conditions demand its application. Shear strength of the 50-50 tin-lead solder runs about 5740 psi. Acid fluxes are recommended, rosin not being suitable because its cleaning action is too mild.

SILVER BRAZING:

Strength and corrosion resistance of properly designed and executed silver-brazed joints are greater than those of soft-soldered joints. Strength of a properly made silver-brazed joint should be approximately 50,000 psi in tension and 30,000 psi in shear at room temperature. These values can be used in design calculations with a factor of safety of five. In shear (lap) joints, drive fits should be avoided. Clearances of 0.002 to 0.005-inch (preferably 0.002 to 0.003-inch), that will permit the molten silver alloy to be drawn through by capillary attraction, are recommended. Excessive clearances of 0.006 to 0.015-inch should be avoided. Not only are such joints wasteful of silver brazing alloy, but also they are lower in strength than those that have been made with proper clearances.

Maximum temperature at which silver-brazed joints can be expected to carry an appreciable load is 600 F, and at that temperature their tensile strength is about 50 per cent of its value at room temperature. Shear-type joints are used more widely than butt joints because of the ease of maintaining better fits and the facility wherewith adequate strength can be obtained merely by extending the lap-shear area.

WELDING:

Nickel can be welded readily by the metal-arc, submerged-arc, atomic-hydrogen, heliarc, carbon-arc and oxyacetylene methods. The flame used in gas welding should be slightly reducing and the work done rapidly and without rewelding. The oxyhydrogen flame is not practicable for the welding of nickel because of its low temperature. Hammer welding is not possible because fusion does not occur unless the metal is melted. In general, the lower limit of thickness of sheet for electric-arc welding is set at 0.037-inch, but, with welding equipment designed for low current densities, thicknesses as light as 0.018-inch have been welded with electrodes smaller than $\frac{1}{16}$-inch diameter.

In gas welding, corner welds and lap joints may be used where high stresses are not encountered. In such equipment as pressure vessels, butt joints are preferred for gas welding since stresses act axially rather than eccentrically as in lap joints. For butt joints in material of 0.050 to 5/32-inch thick, beveling is not required. For V-butt joints in thicker metal, the sheet and plate edges should be beveled to an angle of 37½ degrees to form a welding groove of 75 degrees. For sheet 0.043-inch and lighter, both butt and corner edge welds are used. The appearance of properly made gas welds in nickel is similar to that of good gas welds in steel.

After welding, no thermal or chemical (passivation) treatments are necessary or recommended to retain or restore corrosion resistance. Since the coefficient of expansion is practically the same as for steel, warping and buckling resulting from a welding operation is essentially the same as for a similar construction of steel. Electric welding, if applicable, will produce less buckling than gas welding.

FORGING:

Nickel can be forged readily in dies or by hand methods into almost any shape that can be forged in steel. Temperature range for high-tensile forging is 1000 to 1200 F; for light forging, 1200 to 1600 F; for heavy forging and drop forging, 1600 to 2300 F; and for bending, 1900 to 2250 F. In the heating of nickel, exposure of the hot metal to sulfurous atmospheres or other sources of sulfur is scrupulously avoided. It may be necessary, for some forgings, to use heavier hammers and larger machines than would be used normally in forging steel. This applies particularly to single-blow operations, as in heading rivets and bolts, and in hot pressing. Material for drop forgings should be overhauled to remove the hot-rolling oxide and slight surface imperfections. Since nickel cannot be forge or hammer-welded and is not "free-scaling" during forging, drop forging dies and operations should be laid out so that forging laps will not occur.

ANNEALING

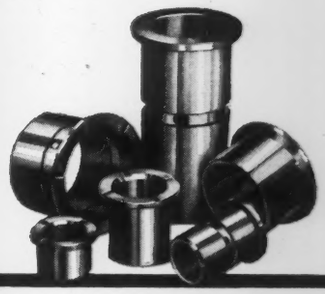
Cold working of nickel work-hardens the material and annealing may be required between operations. For example, when drawn shells reach a rockwell hardness of 95 B or over, annealing usually is necessary. Lubricants and other foreign matter always are thoroughly removed before annealing which can be done by either the box or open methods. Box annealing may be used for small pressed parts, rivets, wire and strip in coils, and such items. Open annealing in oven-type reverberatory furnaces is used for larger cupped and drawn shapes, spinnings, rods, tubes and other forms. Low-sulfur heating medium is necessary for heating nickel.

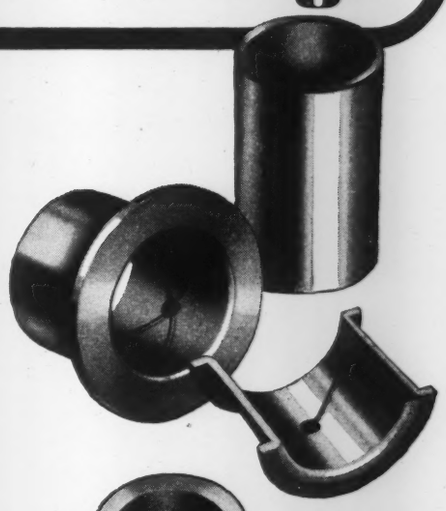
RESISTANCE TO CORROSION

As a general rule, under oxidizing conditions nickel is susceptible to corrosion, while reducing conditions retard corrosion. Nickel will remain reasonably bright and free from tarnish indoors, but it becomes dull when exposed outdoors and tends to acquire a very thin, adherent corrosion product. Rate of attack outdoors is extremely slow and varies with atmospheric conditions. Sulfurous atmospheres encountered in industrial and urban communities are naturally most corrosive. Marine atmospheres are scarcely more corrosive than suburban or rural atmospheres. Nickel is not subject to season cracking and other forms of stress corrosion in atmospheric exposure. In both natural and distilled water, resistance is excellent, while in sea water, resistance is poor except when exposure is at high velocity or in contact with steel, under which conditions nickel is highly resistant to attack.

Nickel offers good resistance to neutral and alkaline salts, acid salts, alkalies and dry gases. Its resistance is generally poor to oxidizing acid and alkaline salts, oxidizing acids, and some of the wet gases. It should not be used in contact with such molten metals as aluminum, tin, lead, solder, bismuth, antimony, zinc or brass. It has good resistance to organic acids and compounds under conditions generally met.

There is ONE RIGHT SOURCE *for* Sleeve Type Bearings





There are several reasons why many leading manufacturers regard Johnson Bronze as the RIGHT source for *all* their Sleeve Bearings. For instance, we are the only bearing manufacturer that produces ALL types of Sleeve Bearings. This enables us to help the purchaser select the correct bearing for each application. It permits us to give sound bearing advice . . . based on facts . . . without prejudice for any one type. Every bearing we produce is manufactured complete in our plant . . . from molten metal to finished product. Thus we have constant control over every step in the process. We manufacture only one type of product . . . Sleeve Bearings. All of our facilities, our resources and research has but one objective . . . to give our customers better bearings at lower cost. Isn't this the type of bearing service you have been looking for? Your inquiry carries no obligation . . . why not write TODAY?

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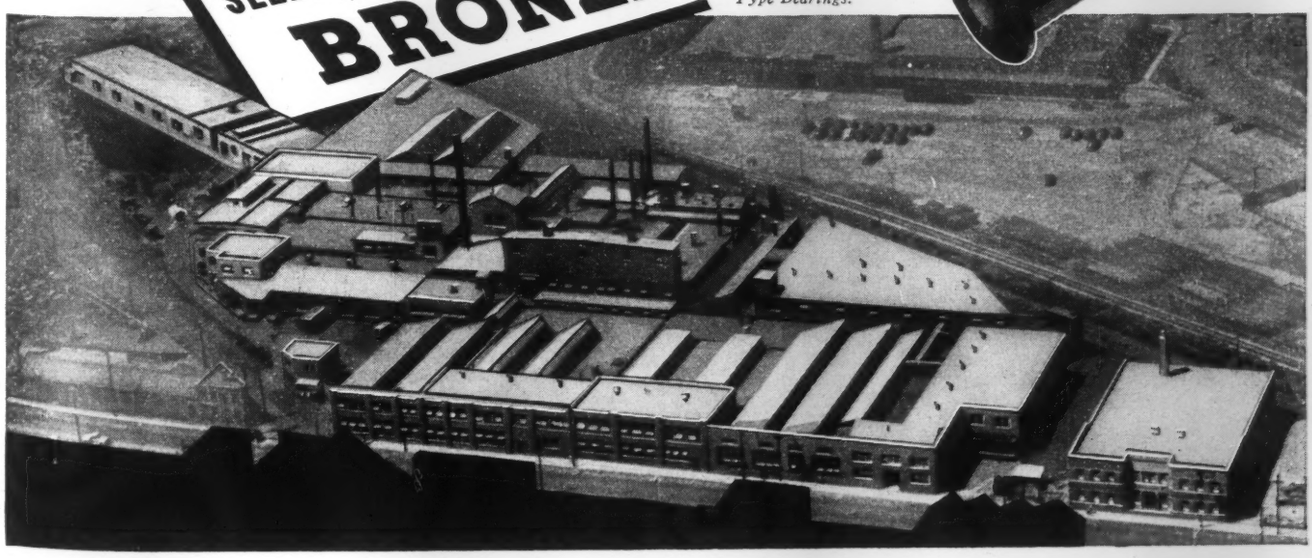
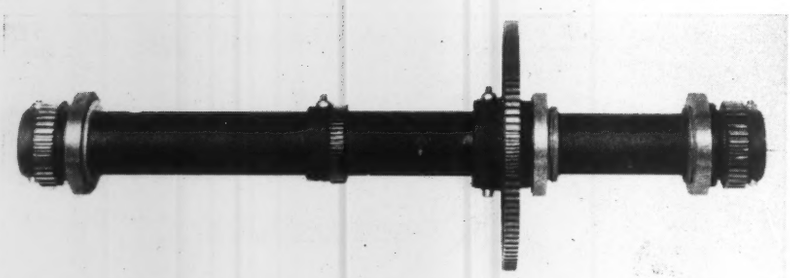


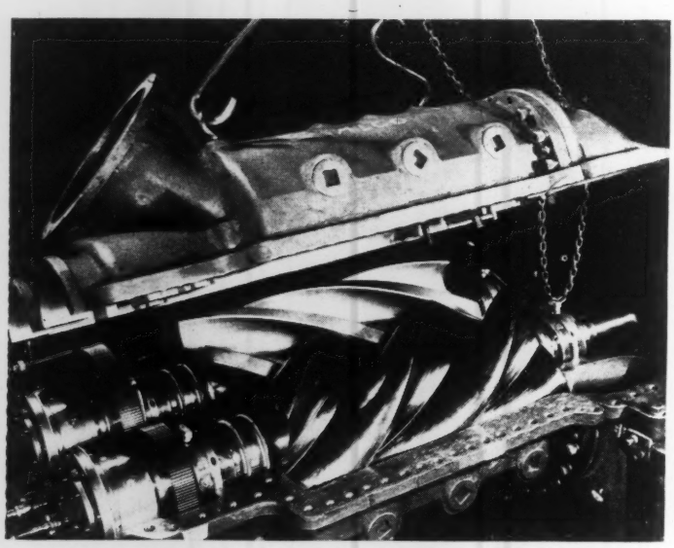
Applications

of Engineering Parts, Materials and Processes



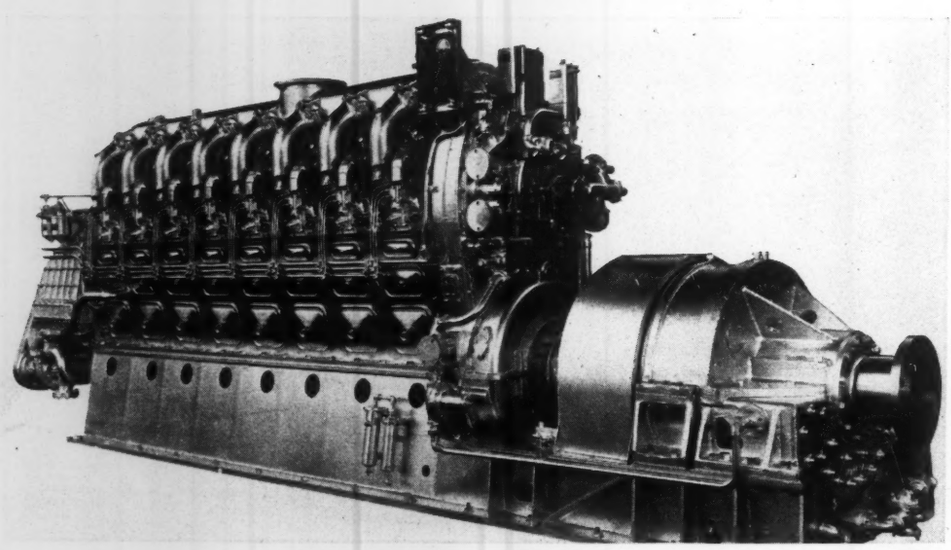
Torque Tube Is Built-Up

END plugs and sleeves brazed to thin-wall tubing by the Voss Bros. Mfg. Co. provides a lightweight, high-strength torque tube for aircraft gun turrets. Shown at the left, the torque tube assembly is brazed in a special salt-bath type furnace at a temperature of 1450 F. Brazing takes but 7 minutes and after cooling and sand blasting the tubes are subjected to a torque test of 2000 inch-pounds. Gears for the drive mechanism are taper-pinned direct to the brazed sections after machining.



Aids Turbine Design

VITAL parts of the compressor for the new Elliott gas turbine, left, such as the upper and lower inlet heads, rotors and thrust bearing housings are cast from Meehanite. Rotors, silver soldered to the rotor shafts, revolve at a top speed of 18,000 fpm necessitating extremely close machining tolerances and in addition structural stability to retain this accuracy under temperature variations up to 150 F. Meehanite provides good machinability and resistance to creep and elongation as well as freedom from galling at high rubbing speeds.



Shockless Marine Drive

MARINE reverse gear shown at the left coupled to a General Motors 2000-hp, 2-cycle, 16-cylinder diesel engine is controlled by a Fawick Airflex clutch and brake. Air pressure introduced into a rubber-and-fabric air gland in the units controls the clutching and braking action. Resilience of the glands absorbs shock, vibrations and heavy starting and stopping torques. Operation is handled by means of air valves—no arms, levers or gears, with attendant lubrication and maintenance problems, being necessary.

STYRON

DOW POLYSTYRENE

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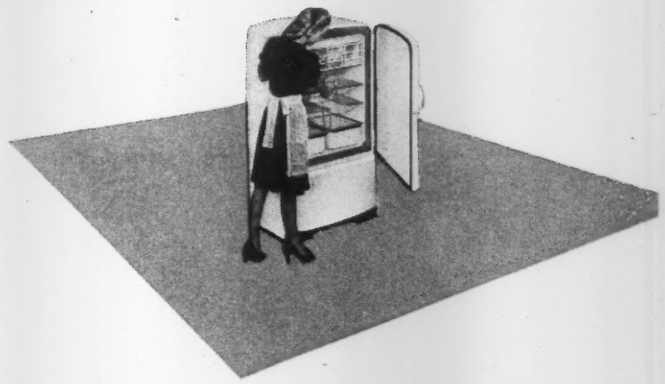
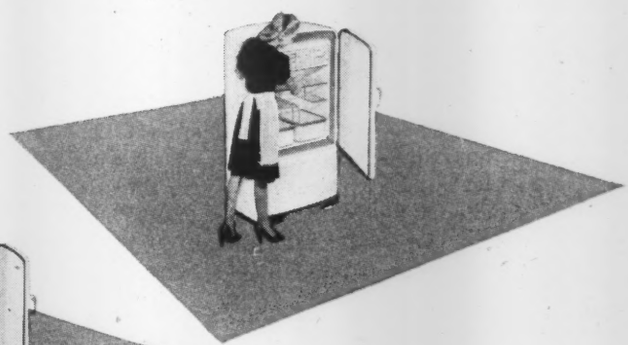
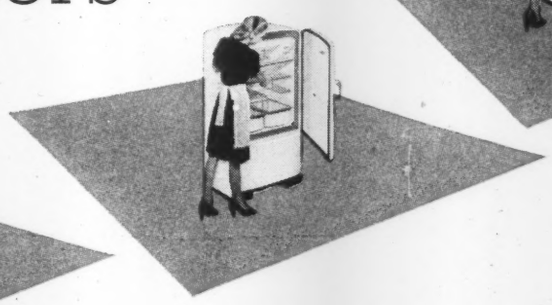
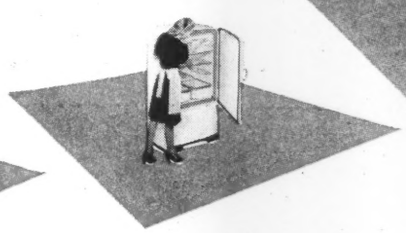
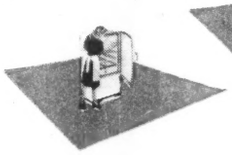


rated no. 1 in refrigerators









Styron is a name that is growing in the refrigerator and other forward-looking industries—with reason!

Modern refrigerators gain a new measure of attractiveness—along with rugged serviceability—with parts made from this Dow plastic. Styron's easy moldability, low water absorption and dimensional stability at low temperatures are qualities that give it unique value for profitable production of fine refrigerators. That's why Styron is rated No. 1 in making ice compartment doors, crisper fronts and numerous other parts for today's leading refrigerators.

But its broadly useful properties and low price dictate the choice of Styron for a wide variety of products. Styron conveys clear brilliance to costume jewelry and cosmetic containers. Its acid resistance recommends it for batteries. Its high dielectric strength and low specific gravity suggest an ever-growing list of applications.

In refrigerators, in numerous products—Styron is the name you can *depend* on in plastics!

Let's work it out together

Success in plastics is measured only in end products. It calls for the combined efforts of manufacturers, designers, fabricators and raw material producers. Dow is ready to do its part. Call on Dow and get the most out of plastics.

PRESENT AND POTENTIAL USES: Lighting fixtures; insulators, battery cases; hydrometers; funnels; closures; food handling equipment; pharmaceutical, cosmetic and jewelry containers; costume jewelry; novelties; refrigerator parts; pens; pencils; liquor dispensers; escutcheons; chemical apparatus; dishes; lenses; decorative objects, trim.

PROPERTIES AND ADVANTAGES: Clear, translucent or opaque; broad color range; excellent high frequency electrical insulator; can "pipe" light through curved rod, and around corners; resistant to acids and many alkalies; low water absorption; light weight; stable at low temperatures; limited solvent resistance; available only in rigid forms.

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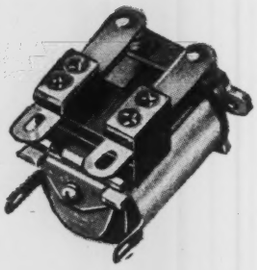
THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN • New York, Boston, Philadelphia, Washington, Cleveland, Detroit, Chicago, St. Louis, Houston, San Francisco, Los Angeles, Seattle

NEW PARTS AND MATERIALS

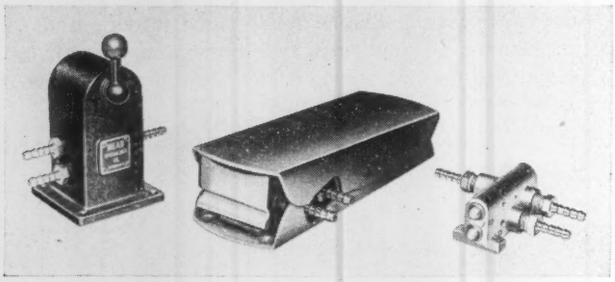
Relays for Precision Operation



CLAIMED TO BE efficient on precision applications in industrial and special control circuits, a new control relay is being produced by Allied Control Co. Inc., 2 East End Ave., New York. Designated as the "CR" Type, this compact lightweight relay is available in two, three and four-pole combinations. The relay can be hermetically sealed. Contact rating with ¼-inch silver contacts is 15 amperes at 24 volts direct current, or 110 volts alternating current, noninductive. Extra heavy gram pressure inherent in the design of this relay permits power switching. The single-pole relay weighs 3 ounces, and is 1 33/64 inches high, 1 3/32 inches wide and 1 25/32 inches long.

Three or Four-Way Air Valves

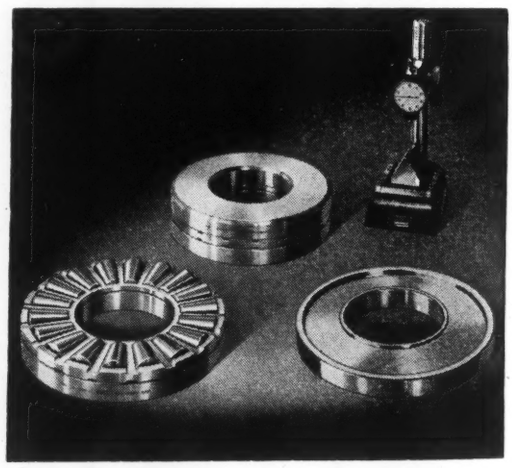
COMBINATION THREE-WAY or four-way air valves, now being marketed by Mead Specialties Co., 4120 North Knox Ave., Chicago 41, have a variety of uses. Model 4WB bench valve has a hand lever in vertical position which closes the air line and opens exhaust ports from cylinder or cylinders. When lever is moved 90 degrees to the



right, it admits air to the cylinder connected to the right-hand nipple, and when moved to the left, it operates the left-hand cylinder. It will also operate a double-acting cylinder in either direction. This valve can function as a 4-way valve, two 3-way valves, one 3-way valve and a 3-way valve and a blower. The Model 4W foot control contains a cam working the valve either as a 3-way or a 4-way type. An adjustable stop in the pedal base provides a quick change from 3-way to 4-way operation. The same combinations of functions can be made by this model as the Model 4WB type. For cam operation, Model 4WC can be mounted on a drill press or other machines for automatic control of air cylinder, by means of cams.

Conical Roller Bearings

CONICAL ROLLER thrust bearings supplement the straight roller type produced by The Kaydon Engineering Corp., Muskegon Mich. While the conical bearings are used extensively in oil field swivels, where they must carry



the entire weight of drill pipe on wells with depths over 15,000 feet, they have many applications in steel mill equipment, paper mill machinery and other heavy duty equipment. The design of this bearing is such that the apex of the cone formed by the rollers meets at the center of the bearing, permitting rollers to align themselves between the tapered faces and the outside rib of the raceways. A one-piece bronze cage acts as a separator. Higher speeds are easily handled by the new bearings. The bearings are available in a complete series of standard sizes, from 9⅞ inches to 19½ inches outside diameter, with load capacities up to 440,000 pounds.

Flexible Plastic Tubing

HAVING UNUSUAL heat-resisting qualities, a new flexible plastic tubing, known as Fibron, has been developed by Irvington Varnish & Insulator Co., Irvington, N. J. In addition to the previous advantages of flexible plastic

UNDERCUTS

In designing die castings, undercuts (recesses in casting walls) are usually avoided since they necessitate slides or "knockout" cores in the die and thereby increase production costs. There are occasions, however, when undercuts can be completely justified, as in the die casting here discussed:

The designers of the illustrated zinc alloy die cast carburetor body were anxious to minimize the amount of metal required per casting since the production run on this part is very large. Considerable metal was eliminated through the use of the undercuts indicated on the drawing, and this saving easily offset the extra die cost involved in providing slides. Furthermore, the undercuts made section thickness of the casting more uniform, which is highly desirable because uniformity of section tends to avoid unequal shrinkage.

There are also cases where interior undercuts, of the type requiring loose cores ("knockouts"), are justified even though the time of the casting cycle is increased and the die cost is higher. *There is no logic, however, in employing undercuts of any kind when they provide no compensating advantages.*

Additional data on undercuts will be found in our booklet "Designing For Die Casting." To insure that you will get the most from your die casting dollar, ask us—or your die casting source—for a copy of this booklet.

ZINC
FOR DIE CASTING ALLOYS

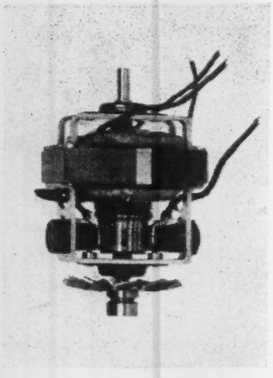
THE NEW JERSEY ZINC COMPANY • 160 Front St., New York 7, N. Y.

The Research was done, the Alloys were developed, and most Die Castings are based on
HORSE HEAD SPECIAL (99.99+% Uniform Quality) ZINC

tubing, the new material withstands varnish treatment and baking operations without stiffening where extreme operating temperatures are encountered. The tubing is also resistant to strong acids and alkalies, denatured alcohol, petroleum and its products, and coal tar solvents. According to tests, the tubing has performed satisfactorily in instances where high dielectric and tensile strengths are required.

Small Universal Motors

TO ITS LINE OF small, fractional-horsepower motors, Lear Inc., 110 N. Ionia Ave., N. W., Grand Rapids, Mich., has added its V Series of universal motors for industrial use. A ten-blade fan and open laminated construction provide cooling factors for the motors, designed for continuous duty. The VC type motors are rated at 125 volts, alternating or direct current, and have an output of 1/100 hp at approximately 125 rpm. Of nonreversing type, with clockwise rotation of the shaft at the fan end, the motors have an overall length of 3 21/32 inches, and a diameter of 2 ⅛ inches. On the standard motors of this VC type, the shaft at the fan end is fitted with a 15/32-inch pulley,

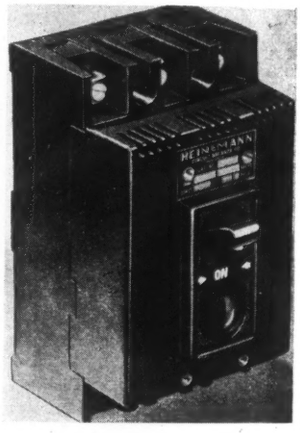


although special shafts or pinions may be specified to meet requirements. The second type, known as the VD class, are rated at 125 volts alternating or direct current, and have an output of 1/30 hp at 7500 rpm. With a 1-inch stack, these motors have an overall length of 4⅜ inches and are approximately 3 inches in diameter. Other specification are similar to the VC type, with the exception that the VD standard motors are equipped with a ¾-inch pulley at the fan end. Rotation of shaft is clockwise.

Hard-Facing Electrodes

FOR SPECIFIC hard-facing applications, Lincoln Electric Co., 12818 Coit Rd., Cleveland, has introduced one new and one improved shielded-arc electrode. Abrasoweld AC is designed for building up straight carbon steel, low steel or high manganese steel with a self-hardening deposit to resist abrasion and impact. Although specially designed for operation on alternating-current industrial type and small. mass-market type welding machines, it can be used on direct-current machines. This new electrode is available in 1/8, 5/32 and 3/16-inch sizes, in 14-inch lengths, and hardens rapidly under conditions of impact and abrasion. Manganweld A, which had been suspended for the duration, has been improved and is particularly well suited for use with direct-current machines. It also can be used with both the industrial type alternating current, and small mass-market type welding machines. Generally recommended for flat work only, the electrode produces a flat bead and melts uniformly with minimum spatter. Deposit is air-toughening and has a resistance to abrasion and impact equal to heat-treated cast manganese steel. This improved electrode is furnished in 5/32, 3/16 and 1/4-inch sizes, in 14-inch lengths.

Three-Pole Circuit Breaker



IN ORDER TO complete its line of general purpose magnetic circuit breakers in the 50-ampere frame size, a new three-pole type with three trip units that act immediately on short circuit or dangerous overload, is being offered by Heinemann Circuit Breaker Co., 113 Plum St., Trenton, N. J. A true inverse time delay in a hermetically sealed unit is provided which allows passage of harmless current surges while continued overload opens the breaker in time inverse to the ratio of the current. If an overload or short circuit occurs in any one leg, the three trip units open simultaneously. Lighter in weight than previous three-pole models, the breaker is designed for service on 120/230 volts alternating current or 250 volts direct current, of 50 amperes maximum. Overall dimensions are 5 1/4 x 2 11/16 x 3 inches.

Electronic High-Speed Counter

DESIGNED TO fill the need in fields unable to employ conventional mechanical counters, an improved electronic high-speed counter has been introduced by Potter Instrument Co., 136-56 Roosevelt Ave., Flushing, N. Y. The unit is particularly applicable for counts exceeding 10 cycles per second. It can be used alone as a two-decade instrument, the maximum count capacity in this case being 100. For cases in which the quantity to be counted exceeds 100, a tube-operated relay is provided that operates once for each 100 counts. The relay has single-pole, double-throw contacts which are brought out to terminals on the front panel. An electromechanical counter may be connected in series with these terminals and the appropriate external power source, such as the alternating-current line. Each 100 counts of the electronic counter will then cause one operation of the electromechanical counter. When counting is terminated, the electromechanical coun-

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J&L ELECTRICWELD TUBING

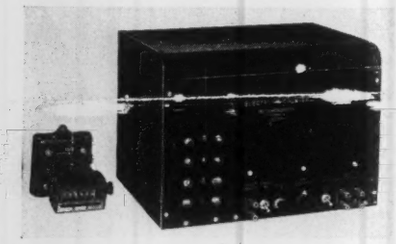
Designers of modern machines and equipment are developing many applications for J&L Electricweld mechanical tubing that save machining costs, increase strength without increasing weight, and improve the appearance of the finished product. J&L Electricweld mechanical tubing is produced from J&L Controlled Quality strip by men of experience and skill. We invite your inquiry. Write or phone your nearest J&L District Sales Office.

J&L STEEL

JONES & LAUGHLIN STEEL CORPORATION

PITTSBURGH, PA.

ter will read the first figures, or places, of the count and the electronic counter will read the final two places. When used with an external mechanical counter, the limitation in operating rate is that imposed by the latter. When operation of the relay and an external mechanical counter is not involved in the application, the electronic counter alone may be used at counting rates up to 20,000 per sec-



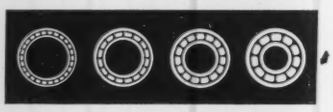
ond. The counter is furnished complete with power supply, and operates from a nominal 115 volts, 60 cycle, alternating-current power line. Outside dimensions of the instrument are: Width, 13½ inches; height, 8⅞ inches; depth, 10 inches. Weight is 26 pounds.

Gapless Piston Ring

DEPARTING FROM conventional rings, a new piston ring offered by Auto-Diesel Piston Ring Co., 3267 Superior Ave., Cleveland 14, consists of two identical parts interlocking when completely assembled and forming a ring without a gap. A positive seal is made with no chance of blow bys. This new gapless ring is adapted for carrying oil within itself, if desired, and can also be used as an oil ring while retaining its expanding features. It can also be made a contracting ring for sealing shafts, bearings, for replacing packings, etc., and for other applications on stationary and mobile units and hydraulic and pneumatic operated industrial equipment.

Ultralight Ball Bearings

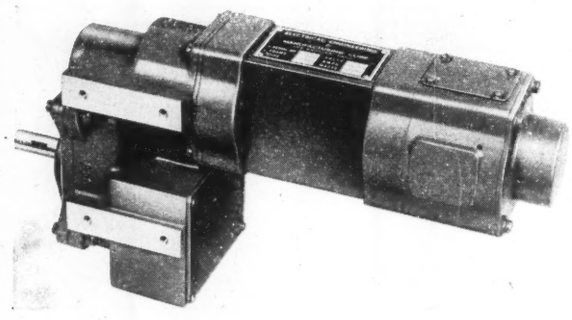
NOW AVAILABLE from Miniature Precision Bearings, Keene, N. H., is a new series of ultralight miniature ball bearings with outside diameters of 5/6-in. and bores of 7/32, 3/16, 5/32 and 1/8-inch. Of chrome bearing steel,



finished to precision tolerances of +0.0000 −0.0002, the bearings are shown in actual size in the accompanying illustration. For use in small motors, computers, electronic equipment, drive movements of recording devices, testing and laboratory equipment, and supporting moving parts of various precision mechanisms, the bearings are suitable for heavy loads and high speeds.

Automatic Door Actuator

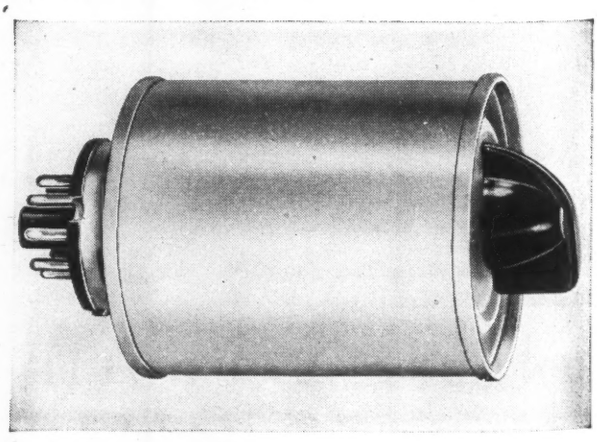
BECAUSE OF the growing need for a specially designed door actuator for railways, subways and street cars, an electrical actuator has been produced by Electrical Engineering & Mfg. Corp., 4606 West Jefferson Blvd., Los Angeles, to provide fast and smooth action in opening and closing automatic doors. Doors open gently, travel rapidly when underway, and slow down before reaching the wide-open position. In the closing half of the cycle, doors start gently, travel rapidly underway, and slow down before closing. These characteristics prevent shocks to the door mechanism, eliminate slamming and provide ample speed.

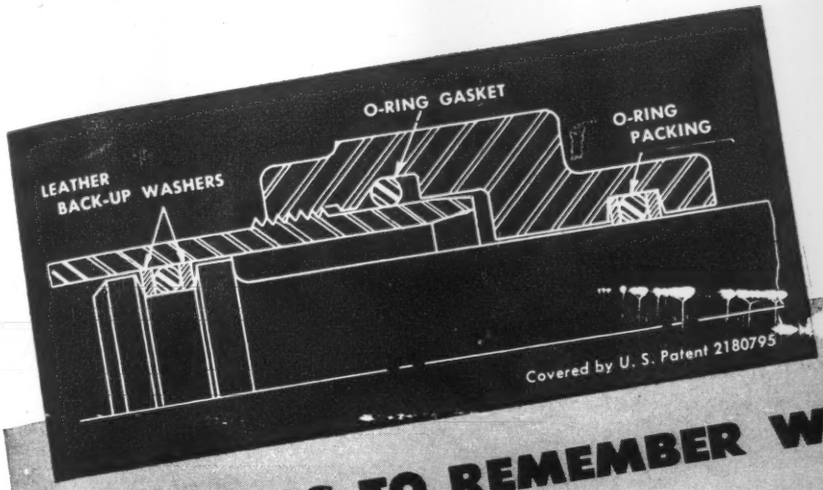


Designed for instant reversing, the unit can be overridden in case of power stoppage. Being vibration proof and having built-in thermal protection, the actuator operates on 32, 64, or 110 volts, direct current, and can be modified to operate on 110 volts, single-phase, alternating current. Starting torque is 250 inch-pounds; average torque at 105 revolutions per minute is 170 inch-pounds.

Self-Timing Interrupter

COMPRISED OF a glass-enclosed thermal element of the hot-wire type, a small power relay, and a resistor (when required) to apportion flow of current between the thermal element and the relay coil, an enclosed self-timing interrupter can be supplied with a fixed, predetermined





2 THINGS TO REMEMBER WHEN YOU BUY "O" RINGS:

1 Buy them from a licensed source and avoid patent infringement. Houghton is a licensed supplier.

2 Use leather back-up washers when pressures exceed 1500 lbs., and assure greater efficiency from the "O" rings. Houghton makes leather washers, too.

• • •

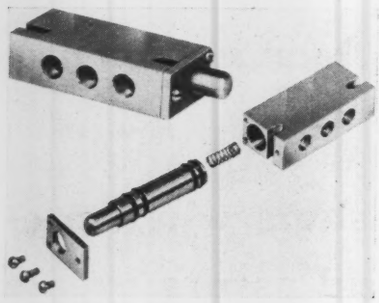
For a single source of supply, for highest quality materials, and for expert engineering advice, contact E. F. HOUGHTON & CO., 303 West Lehigh Avenue, Philadelphia 33, Pa.

HOUGHTON'S
VIM Leather and **VIX-SYN** Packings

rate of interruption or with an external variable adjustment. The fixed unit can be furnished in either open frame construction or in plug-in metal enclosures (dust cover or hermetically sealed) while the adjustable unit is available in plug-in dust cover enclosures only. Timing range is 1 to 12 pulses per second; voltage, to 32 volts direct current and 125 volts, 60-cycle alternating current. Contacts may be single-pole single-throw, normally-open or normally-closed (double break), double-pole single-throw, normally-open or closed, or double-pole double-throw. Contact rating is 10 amperes (noninductive load at sea level). The interrupter, announced by Electronic Controls Inc., 44 Summer Ave., Newark 4, N. J., can be used for warning signals, flasher lights, industrial controls, life testing circuits, truck or bus blinkers, process timing and aging equipment control.

Pneumatic 3-Way Pilot Valve

FOR OPERATING air cylinders, air motors, air controls and single-acting cylinders such as those used on machine tools, a new CRV pilot valve of Modern Products Ltd., 952 South Grand Ave., Los Angeles 15, is designed to be used as a 2-way or 3-way valve, normally open or closed. Operated by hand, foot treadle or cam, the valve is 3¼ inches overall, with piston fully extended. Aircraft type packings on piston rod as bearing points are utilized, eliminating



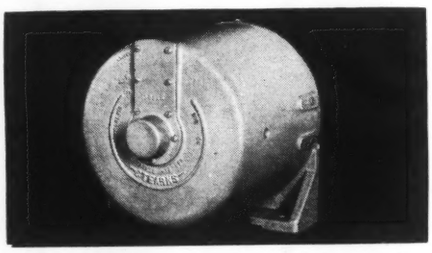
metal-to-metal contact. Plunger of the valve does not come out of the housing during operation as the piston rod is retained by an end-plate. Fully balanced and operating under conditions of extreme pressure variation, the valve is normally supplied with ⅛-inch inside pipe thread ports. Other sized ports or threads may also be furnished upon request.

Improved Rayon Hose

AN IMPROVED industrial hose for hydraulic and air systems is being offered by J. N. Fauver Co., 49 West Hancock Ave., Detroit 1. This hose is the same Oilresist hose produced by the company, but reinforced with two-ply rayon cord instead of the cotton fabric previously used. According to the company the rayon cord hose has 25 per cent greater burst pressures and proportionately higher working pressures, weighs less, has smaller outside diameter for the same inside diameter, has good flexibility and does not stretch or elongate under pressure. Suitable for conducting oils, greases, steam, water and similiar fluids on machinery, the hose is available in mill lengths or made to order in assemblies of any desired length. Sizes range from 3/16-inch to 1 inch inside diameter, with maximum temperature of 235 F, and working pressures to 800 lb.

Magnetic Disk Brakes

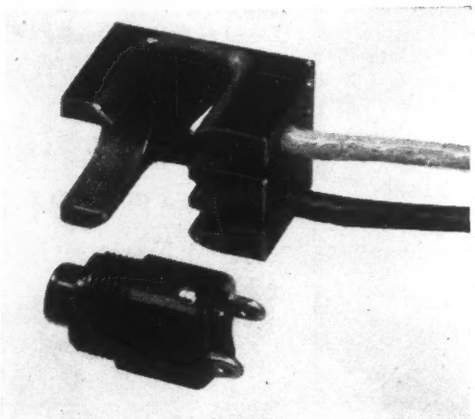
SERIES 1300 magnetic disk brakes, developed by Stearns Magnetic Mfg. Co., Milwaukee, are designed for applications up to 100 hp motor-driven loads. These brakes can be supplied in either floor or motor mounted



types for either alternating or direct current. Design of the brakes is so simplified that replacement of any part can be made where necessary without disturbing the brake assembly. This new series augments the company's present Series 800 and 1000 brakes.

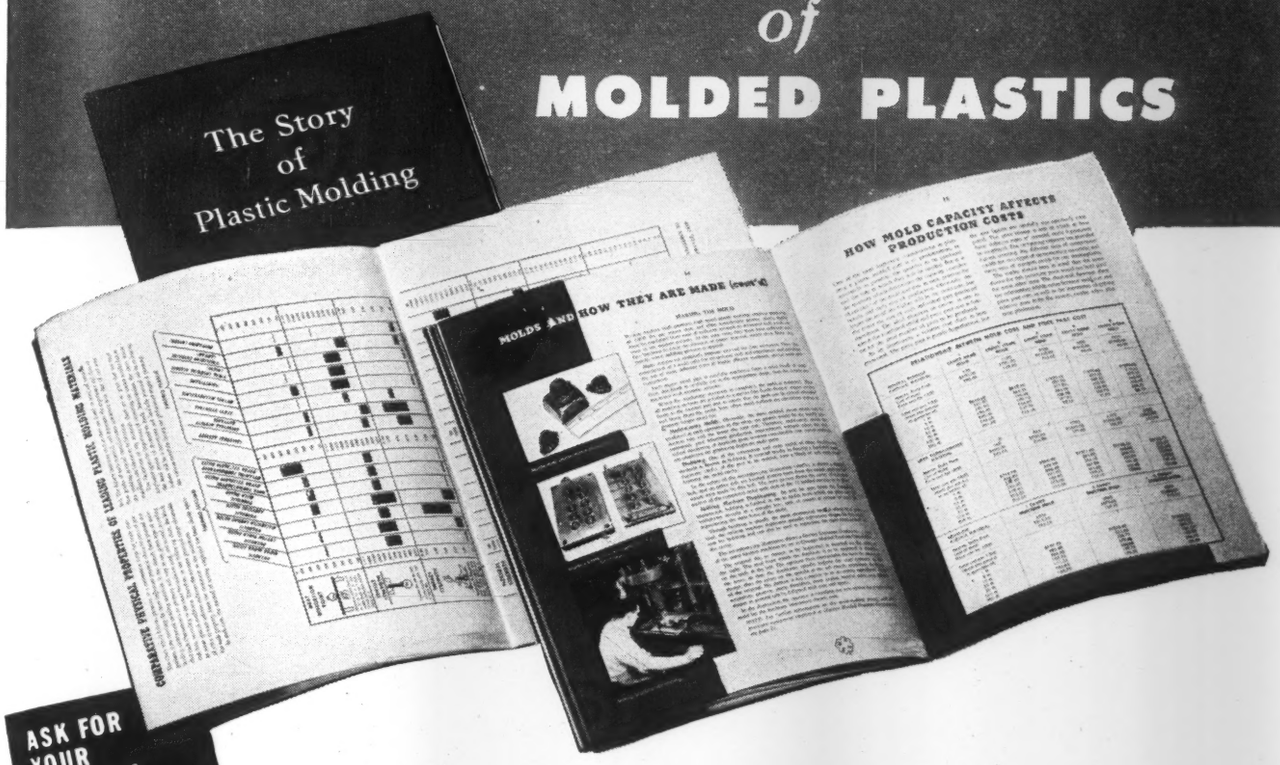
Small Renewable Switch

OF RENEWABLE type a single-pole single-throw switch, either normally-open or normally-closed, is being offered by Robert Hetherington & Son Inc., Sharon Hill,



Pa. It is an adaptation of a small switch brought out by the company recently, and can be used in a single-hole mounting. The switch has two flat studs protruding from the back to which lugs are frequently attached. When

For Buyers . . . and Prospective Buyers of MOLDED PLASTICS



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Are plastics applicable to your needs? . . .
Which plastic is best suited to your job? . . .
How will design affect production volume and cost?

These are some of the things you should know *before* you have gone far with your plans and *before* you have designed the part to be molded.

These questions, and many more equally pertinent, are authoritatively discussed in our new book, "The Story of Plastic Molding." Charts, tables, and illustrations are used prolifically to explain each point. Result—a clearer understanding of the possibilities of molded plastics for your particular use, as well as their limitations.

Yes—this book is brimful of down-to-earth facts . . . information that is based on our quarter century of experience in plastics. We believe that you, like thousands of others, will find it useful and valuable . . . a book you will want to keep and *use*.

Write for your copy today . . . on your firm letterhead, please. There's no charge . . . no obligation.

Here are a few of the subjects covered:

- When to use molded plastics (also when *not* to use them).
- Choosing the right material.
- Comparative physical properties of molding materials.
- The molding process.
- How molds are made.
- Relationship between mold cost and piece part cost.
- Designing for plastic molding.

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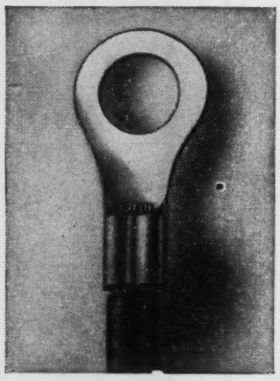
COMPRESSION AND INJECTION MOLDING OF ALL PLASTIC MATERIALS

switch is used as a renewable type, the studs slide down between two contact bars which are in the back part of the cradle. The unit has been approved for 15 amperes 110 volts alternating current, for either motors or resistive loads such as heaters or lamps. It is a little over an inch long and three-quarters of an inch high.

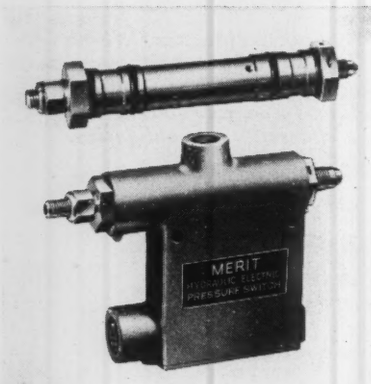
Solderless Terminals



SOLDERLESS terminals have been announced by Aircraft - Marine Products Inc., 1591 North Fourth St., Harrisburg, Pa., for mass production wiring, using stranded wire sizes 22 to 14. These "Budget Line" terminals can be installed at a rate of 600 an hour at a low cost. Connections are clean and uniform, and can be inspected visually. Crimp permits use of shorter than standard terminals without sacrifice of electrical or mechanical characteristics. Crimping action employed gives maximum inside surface contact with the conductor.

Hydraulic Electric Switch

OUTSTANDING FEATURE of the new precision hydraulic electric switch of Merit Engineering Inc., 40 Clifford St., Providence 3, R. I., is its long life under severe conditions. In tests carried on in temperatures varying from −60 to 160 F, maintained over extended periods of constant make and break, no appreciable wear was noted. The hydraulic valve which actuates the switch is a self-



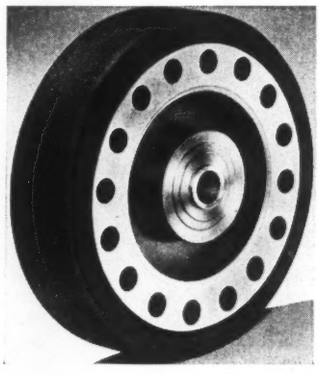
contained cartridge, renewable and interchangeable. With two cartridges, having different springs, the entire operating range of 100-3200 psi is covered. This direct-current switch is a single-pole, single-throw, normally-closed type. The rating is 40 amperes 28 volt inductive load; 17 amperes 125 volt; and 8½ amperes 250 volt noninductive load. Overall dimensions are 4.5 x 4.08 x 1.14 inches; weight with aluminum body, 22 ounces.

Sealing Compound

A NEW GENERAL-PURPOSE thread and gasket sealing compound produces a seal which is proof against air, water, steam, gas, gasoline, oil, hydraulic fluids, and aromatics. Known as Uniseal, and offered by Parker Appliance Co., Cleveland, it is a paste of uniform consistency, containing no free metallic particles or other additives subject to washing out. Flowing smoothly to form ribbon gaskets and blending readily with cut gasket material, it possesses good antiseize characteristics which aid in assembling of threaded fittings. Solubility in alcohol and carbon tetrachloride simplifies any necessary cleanup, or disassembly of previously sealed work. Tests, according to the company, show Uniseal to be effective under severe conditions of vibration and at temperatures above 300 F. It is available in tubes and containers ranging from 8 oz to 5 gal.

Tread-Lock Wheel

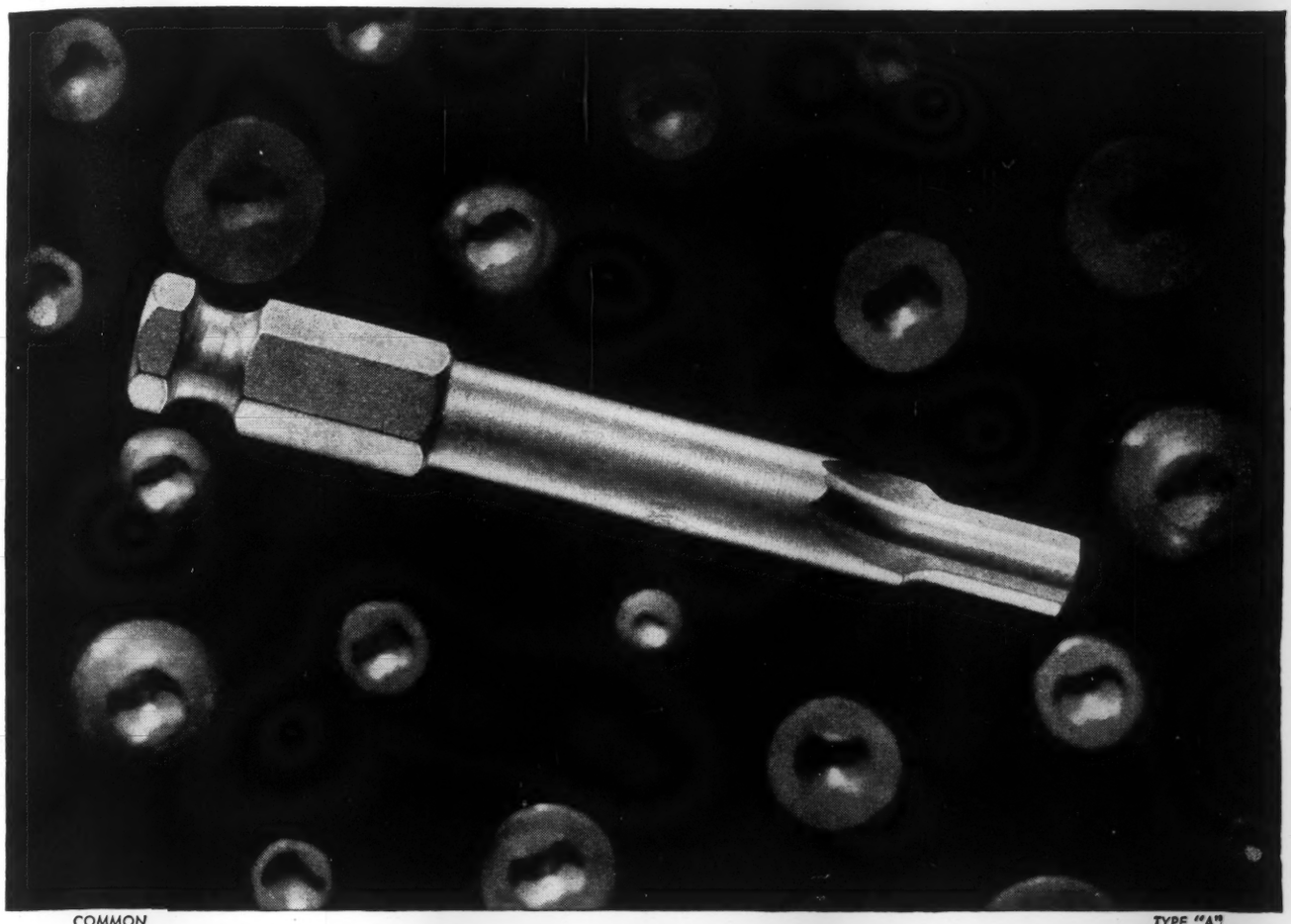
TREAD-LOCK WHEELS used on carrier-based aircraft of all types have now been adapted to industrial use. The sealed-in lubrication of the wheels insures proper lubrication for life. Another feature of the wheels, produced by Thermoid-Grizzly Wheel Sales Division, Thermoid Co., Chicago, is the "breather" holes in the casting, allowing the



rubber tire to expand under pressure and to contract when pressure is removed. This makes for a "no-bulge" tire. While the cut-resistant tread is tough and will not pull apart or chunk-off under any condition, it is also gentle to floors and will not mar surfaces. The standard sizes in which the wheel is available include 6, 8, 10 and 12 inches, with special sizes made to order to fit all standard axles.

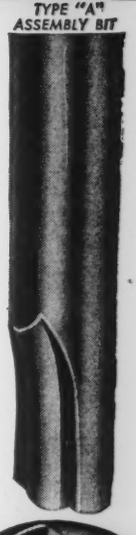
Rust Preventive

EMULSION TYPE cleaner, PSC, for use in power spray washers cleans ferrous and nonferrous metals and inhibits them against rust, corrosion and hand soil. Announced by Phillips Chemical Co., 3410 W. Touhy Ave., Chicago 45, the cleaner is nontoxic and noninjurious to skin, re-



COMMON SCREWDRIVER

TYPE "A" ASSEMBLY BIT



How Many Thousands of Screws Per Bit?

CLUTCH HEAD users have the answer to this question . . . for that is how they measure the economy and efficiency of screw driving on their assembly lines.

The explanation of this unequalled "high-score" driving is simple. It lies in the ruggedness and design of the Type "A" Bit. This ruggedness is self-evident and is made possible ONLY by the mating design of the Clutch recess. This means stamina to stand up through a longer driving spell, free from tool change interruptions . . . speeding up the production tempo and rolling up the record of thousand upon thousand of extra screws per bit.

Note, too, that the driving score of this bit is multiplied time and time again because it may be repeatedly restored to original efficiency by a 60-second application of the end surface to a grinding wheel.

Other special features incorporated in CLUTCH HEAD *Screws contribute importantly to greater safety, higher production, and lower costs. We invite your personal investigation of these and will send you,* BY MAIL, *package assortment of* CLUTCH HEAD *Screws, sample Type "A" Bit, and illustrated Brochure.*

Being operative with an ordinary screwdriver or any flat blade of reasonably accurate width, this is THE ONLY MODERN SCREW *that simplifies your field service problems.*

CLUTCH HEAD SCREWS

Note the straight-walled Clutch matched by straight-sided driver for square engagement, eliminating "ride-out" tendency with hazard of slippage as set up by tapered driving.

UNITED SCREW AND BOLT CORPORATION

CLEVELAND 2 CHICAGO 8 NEW YORK 7

quires no rinsing, and will keep the washing tank clean. It can be diluted with water in proportions of from 1:10 to 1:100, depending upon the type and amount of soil and the length of time rust resistance is required. The process includes washing parts and blowing them dry with air for complete cleaning and rust inhibition. PSC is available in three types: No. 1 for light duty, No. 2 for heavy duty and No. 3 for special rust-resistant qualities.

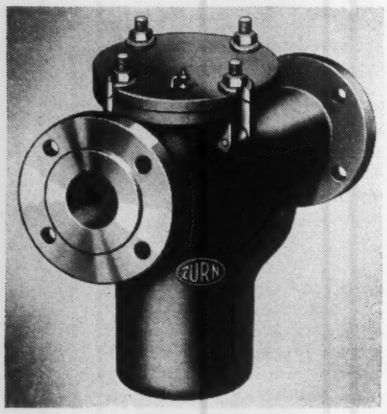
Antivibration Mounting

FOR PROTECTING delicate equipment of all kinds a new antivibration mounting has been developed by Robinson Aviation Inc., Teterboro, N. J. Principal load in the new unit is carried by a stainless steel spring of special

design, with three-way freedom of movement and built-in, three-way limiting snubbers, furnishing a resilient stop to limit heavy shock loads. Performance tests have shown that the unit averages better than 90 per cent absorption of vertical and lateral vibrations over a wide range of frequencies. The Vibrashock units are available in three standard sizes and a wide range of load capacities.

Suction Pipe Line Strainer

PRESSURE AND suction pipe line strainers produced by J. A. Zurn Mfg. Co., Erie, Pa., maintain maximum liquid flow through piping systems and protect pumps and mov-

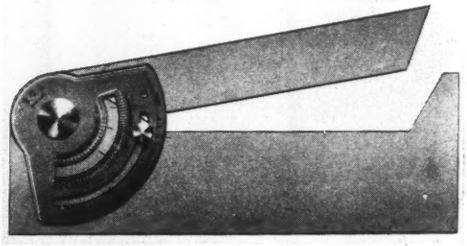


ing parts of associated equipment which might be injured by foreign particles. Maximum liquid flow is assured since the total area of the basket perforations exceeds that of the inlet openings by more than a 1.5 ratio. An air-pressure relief valve on the cover permits escape of air building up within the unit. The unit can also be furnished with a magnetized strainer basket for intercepting ferrous metal particles too small to be held by the strainer. Available for either high or low pressures, the high-pressure strainers have a removable drop-bolted cover while low-pressure strainers have yoke-clamp covers. Strainers may be made in cast bronze, steel or semisteel, depending upon requirements.

Engineering Dept. Equipment

Adjustable Quadrangle

CALLED THE Quadrangle by its producers, Stewart-Jackson Instrument Co., A. G. Bartlett Bldg., Los Angeles 14, a new instrument provides angles from 0 to 90 degrees; pitch scales from 0 to 24/12; percentage slopes from 0 to 100; sine or cosine functions and tangents. It has eight drawing edges, is rectangular in shape, and may be used as a triangle. The body and arm of the instrument are



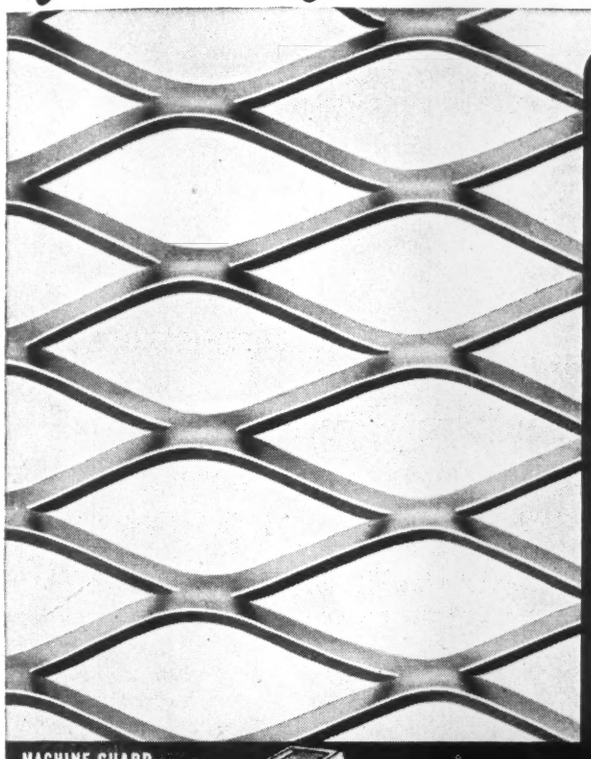
blank so that the engineer or designer may add his own most-used cut out symbols and measuring scale. Overall size is 4 x 11 inches.

Combination Ruler

COMBINATION ruler and letter weigher, offered by Parva Products Co., West Haven 16, Conn., provides eight instruments in one. These include: Letter weigher up to 2 oz., ruler with a 12-inch scale, magnifying glass,

French curve, compass for drawing circles from ½-inch to 22 inches, 180-degree protractor reading 90 degrees in either direction, level, and mitre. It is furnished in ivory plastic, with blue level and blue markings.

light weight with STRENGTH

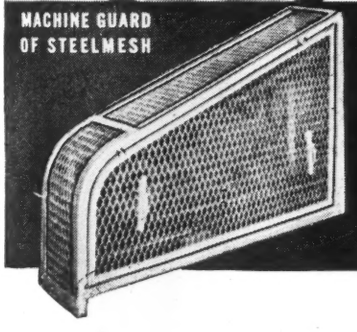


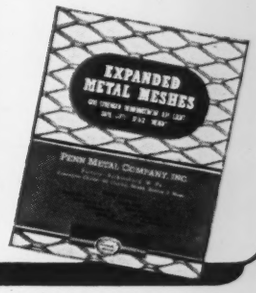
Penmetal Steelmesh

EXPANDED METAL

One square foot of steel plate is expanded to become four to five square feet of Penmetal Steelmesh. No steel waste. The truss-like formation is actually more rigid than the original plate. By using Penmetal Steelmesh for certain parts, a household article has just been designed with a saving of 25% in the total weight. Can be cut, shaped and arc or resistance welded without raveling or joint failures.

Investigate the advantages of Penmetal Steelmesh in the fabrication of your product. *Write for catalog and samples.*





APPROXIMATE SIZES, DIMENSIONS AND WEIGHTS

STANDARD STEELMESH							FLATTENED STEELMESH				
Style Designation	U. S. Standard Gauge Steel Used	Weight in Lbs. Per Sq. Ft.		Stock Sizes of Sheets	Size of Mesh from Centers of Bridges		Weight in Lbs. Per Sq. Ft.		Stock Sizes of Sheets	Size of Mesh from Centers of Bridges	
		Plain	Galv.		Width	Length	Plain	Galv.		Width	Length
½"–#20	20	.50	.63	3′ & 6′ x 8′	.45″	1.2″	.47	.63	3′ & 4′ x 8′	.46″	1.28″
½"–#18	18	.74	.91	3′–4′ & 6′ x 8′	.45″	1.2″	.70	.91	3′ & 4′ x 8′	.46″	1.28″
½"–#16	18	.81	.97	4′ x 8′	.45″	1.2″	.77	.97	4′ x 8′	.46″	1.28″
¾"–#16	16	.50	.59	3′–4′ & 6′ x 8′	.95″	2.0″	.47	.59	3′ & 4′ x 8′	.97″	2.13″
¾"–#13	13	.80	.92	3′–4′ & 6′ x 8′	.95″	2.0″	.76	.92	3′ & 4′ x 8′	.97″	2.13″
1½"–#18	18	.20	.25	2′ & 4′ x 8′	1.34″	3.0″	.....	.....	.....	.....	.....
1½"–#16	16	.40	.48	2′ & 4′ x 8′	1.34″	3.0″	.38	.48	2′ & 4′ x 8′	1.34″	3.20″
1½"–#13	13	.60	.68	4′ & 6′ x 8′	1.34″	3.0″	.57	.68	3′ & 4′ x 8′	1.34″	3.20″
1½"–#10	13	.79	.89	4′ & 6′ x 8′	1.34″	3.0″	.75	.89	3′ & 4′ x 8′	1.34″	3.20″

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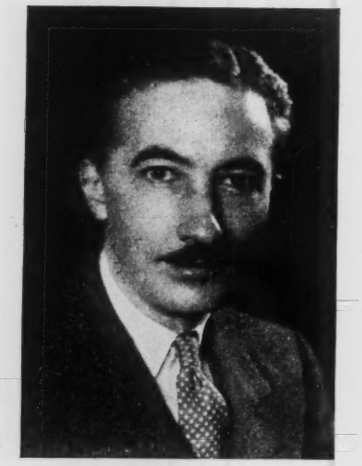
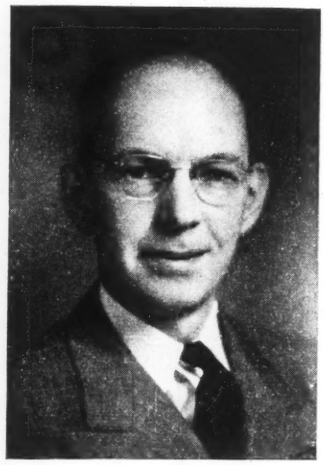
METAL MARK Penmetal 1869 OF QUALITY



S. Floyd Stewart

O. E. Nordberg



John Seagren

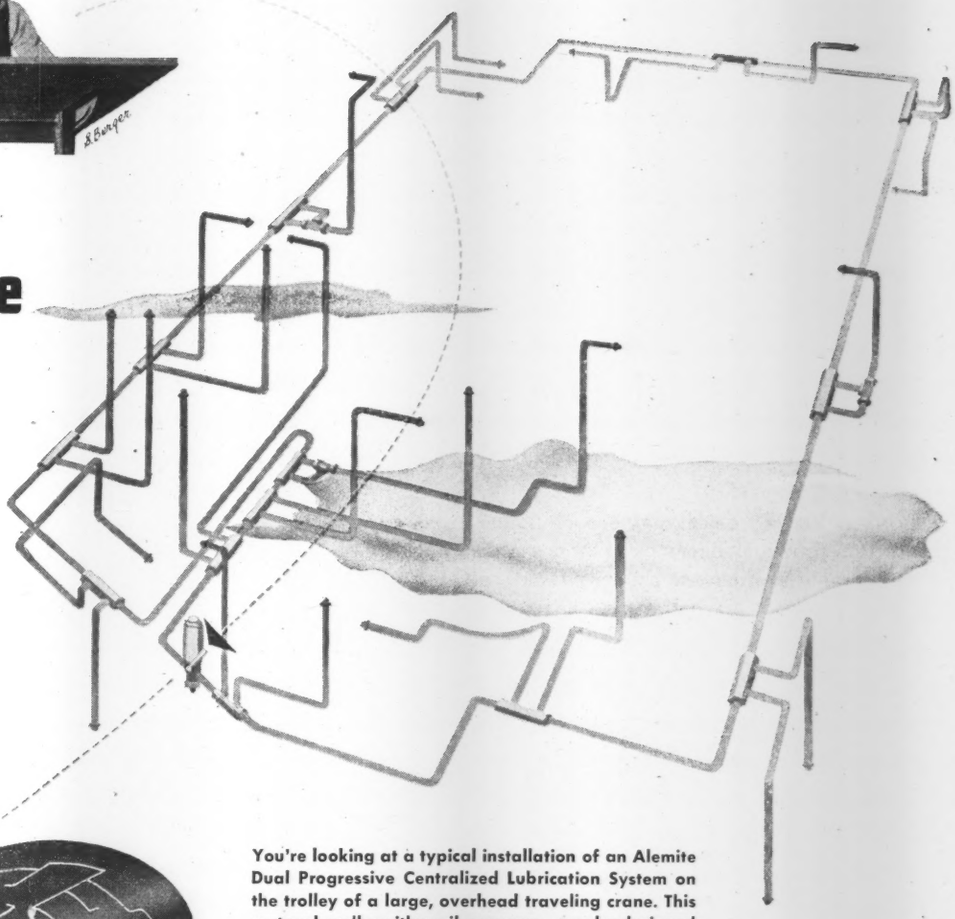
MEN...of...machines

S FLOYD STEWART, associated with The Leece-Neville Co., Cleveland, since 1936, has been elected vice president in charge of engineering. Joining the company as a research engineer, Mr. Stewart became chief engineer in 1941, the position he held prior to his present appointment. He received his bachelor of science degree from Washington university in 1922, and followed this with graduate work at Massachusetts Institute of Technology, receiving his masters degree in 1924. Upon graduation he joined General Electric Co. where he completed its test course. This led to a position in the company's motor engineering department. Later he became connected with the Wagner Electric Corp., as a member of its engineering staff. After serving in this capacity he was associated with the Jensen Co. of Chicago, prior to joining Leece-Neville in 1936.

O E. NORDBERG, who for the past five years has been chief engineer of turrets and appliances and later chief engineer of refrigeration for The Crosley Corp., has been made manager of refrigeration and appliance engineering. Mr. Nordberg will be in charge of development and design of the various appliances such as refrigerators, home freezers, ranges, washers and other equipment produced by Crosley. His experience in household equipment development and design, and particularly in refrigeration engineering, is extensive and varied. For eight years he was connected with the Norge Division of Borg-Warner Corp., and later for two years he served with the Gibson Refrigerator Co. His association with Crosley dates back to 1941. In all of his previous connections, Mr. Nordberg made many engineering contributions to household refrigeration. During the war, he was engaged almost exclusively in war production activities, being in charge of engineering on gun turrets built by the company for Martin PBM bombers.

JOHN SEAGREN as the new chief engineer of the diesel engine division, American Locomotive Co., will have an opportunity to utilize his valuable experience with diesel engines. From 1925 to 1932 he was associated with Fairbanks Morse & Co., first as design engineer, specializing on diesel engines and air compressors, and later as development engineer in the company's research and development department. In 1932 he joined the Atlas Imperial Diesel Engine Co. as development engineer in charge of experimental and

How to Reduce 25 Lubrication Points to 1



You're looking at a typical installation of an Alemite Dual Progressive Centralized Lubrication System on the trolley of a large, overhead traveling crane. This system handles either oil or grease—can be designed into almost any type of machine.

In your mind's eye, picture your machine inside an Alemite System. Those "metal arteries" become the lifeline of the machine. Suppose your "brain child" has 25 points of lubrication, or 50, or 86. Actually with an Alemite System you'd have only *one*—the central point where the lubricant is introduced. From there, all bearings are positively lubricated with a measured quantity of grease or oil *without stopping the machine.*

Proof? A famous factory has a battery of 7 automatic punch presses. It was taking 140 minutes to lubricate them—*and they had to be stopped.* Bearing failures were frequent. Now with an Alemite System, the presses are positively lubricated from one central point in 3 minutes *while the presses are operating.* Bearing failures due to faulty lubrication have ended.

When you design Alemite Centralized Lubrication into your machines you automatically protect their performance from the dangers of human error. You reduce the number of lubrication points to *one.* You guarantee positive lubrication without "time-outs." You cut repairs to a minimum . . . lengthen machine life . . . increase satisfaction. It all adds up to "M.P.T."* per machine. And that enhances your reputation as a designer.

**More Productive Time*

* * *

Without obligation, have an Alemite Lubrication Specialist demonstrate one or all 4 new Centralized Systems right at your desk with transparent working models. Also, ask for any technical help you want regarding Alemite Systems. Drop a note on your letterhead to Alemite, 1804 Diversey Parkway, Chicago 14, Illinois.

ALEMITE

CENTRALIZED LUBRICATION SYSTEMS

ALEMITE HELPS THE WORLD GO ROUND

A Service Product of STEWART WARNER

ALEMITE PROGRESSIVE • ALEMITE DUAL-PROGRESSIVE • ALEMITE DUAL MANIFOLD • ALEMITE LUBROMETER

development work, and four years later assumed full charge of all experimental work and engineering in both the Oakland, Calif., and Mattoon, Ill., plants. In the position of development engineer of Northern Pump Co., which organization he joined in May, 1944, he was connected with the development of postwar products. Approximately a year later he became associated with American Locomotive Co.

♦

HAROLD KOESTER, formerly assistant chief engineer of Righter Mfg. Co., has been made chief engineer of Leyhe Mfg. Co., Burbank, Calif.

♦

PAUL FULLER, who as chief engineer had been connected with Fitzjohn Coach Co., has become project engineer of Continental Motors Corp.

♦

ELLSWORTH D. WILKIN has recently been named assistant chief engineer of Salsbury motors division, Avion Inc., Los Angeles.

♦

DONALD ZUERL, chief engineer of the equipment and production processes department, of the A. B. Chance Co., is now serving in the same capacity with the Danuser Machine Co., Fulton, Mo.

♦

LYNN MATTHIAS, director of research, Allen-Bradley Co., Milwaukee, has been selected as a technical representative of the controller industry to visit motor control plants in Germany and to report to the industry on foreign controller developments.

♦

IVAN H. DRIGGS, director, Aviation Development Research, Bureau of Aeronautics, Navy Department, was recently awarded honorary degrees from Stevens Institute of Technology.

♦

ARNOLD J. HALBFASS has become associated with the Cameron Machine Co., Brooklyn, as design engineer. He had been connected with R. Hoe & Co. Inc.

♦

ARTHUR E. COX, formerly supervisor of draftsmen, Murray Corp. of America, has been made assistant chief body engineer of Graham-Paige Motors Corp., Detroit.

♦

JOHN ROLAND recently resigned as chief engineer of the Stokol Division of Chrysler Air-Temp to become a member of the engineering department of Conco Engineering Works.

♦

RALPH E. MIDDLETON, a vice president of the Aireon Mfg. Corp., has been appointed general manager of the hydraulic division at Burbank, Calif., of which he has been chief engineer since 1941.

♦

A. F. FISHER, formerly vice president in charge of manufacturing and engineering, Northam Warren Co., has been named manager of engineering and manufacturing, Warren Telechron Co.

Atomic Power in Peacetime

(*Continued from Page* 136)

gases must be led off, and the mechanical parts must tolerate the radiation and temperature stresses.

Confining the penetrating radiation of the pile is a far more serious matter than confining the steam or mercury vapor in a typical boiler. The shielding for this purpose must be equivalent to several feet of steel, and there is little prospect that this will be reduced in the typical case. For this reason small fission power plants now appear to be out of the question and a minimum size of perhaps 50 tons is required.

Let us consider the economy of a chain-reacting pile as a heat energy source. The fission energy in one pound of U235 equals the heat energy in 1000 tons of coal. But the plants for the production of U235 and element 94 (plutonium) are expensive to build and operate; General Groves has stated that the Government's investment at Oak Ridge, Tennessee, and Hanford, Washington, totals $1.3 billion and has an annual operating cost of $258 million. He did not state how much fissionable material is produced in these plants. Because the U235 and the other high purity materials of a pile are very expensive today, because the pile structure and its auxiliaries are expensive, and because of the required skilled personnel, heat from a pile is not competitive today with heat from a device which burns conventional fuels.

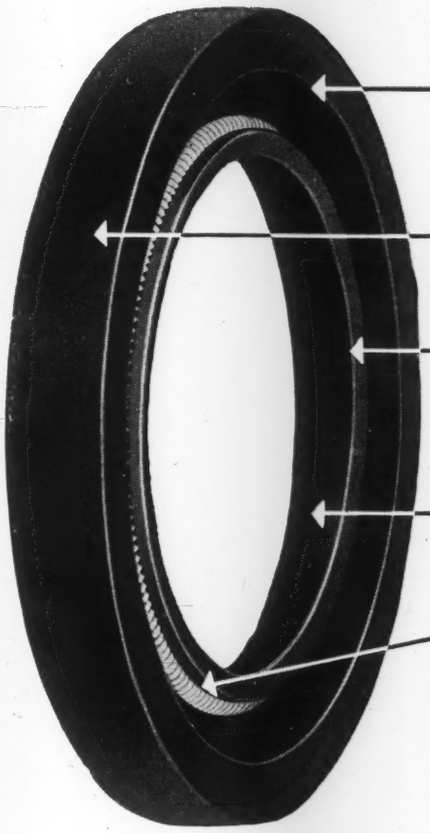
Evaluating Applications of Nuclear Energy

With these basic facts of *today*, we can now consider some prospective applications of nuclear energy, that is, of chain-reacting piles. The fact that they must be large rules out immediately a host of low-power applications such as automotive. Large ship propulsion seems not only possible, but attractive on a strategic rather than a competitive basis. An advantage gained in the space required for fuel is partly offset by the space required for shielding; evidently a detailed research and engineering study will be required to evaluate this application. Perhaps large electric power plants are in the running in areas such as, for example, Australia where there is practically no conventional fuel but abundant natural resources of many other types. Probably at some time in the distant future, atomic power plants for electric power generation will compete successfully with coal, oil and water power energized plants. In fact, this possibility is an important hedge against the ultimate exhaustion of the natural oil and coal reserves. But it should be borne in mind that there is nothing in the present status of nuclear research to justify the hope of direct conversion of nuclear to electrical energy. Hence this competition with conventional fuel, insofar as known today, must be evaluated from a consideration of heat production as a step in the conversion cycle.

What steps must be taken to make nuclear energy successively more competitive with conventional fuels? The required steps are clear, and are primarily research steps. We must study the basic problems of isotope separation. The physical and chemical reactions of the pile must be exhaustively studied with heat production as the objective. The host of serious metallurgical problems associated with the strength, durability and radiation properties of alloys

NEW TYPE *non-metallic* OIL SEAL

simplifies design problems... reduces bearing maintenance



One-Piece Precision Molded Body—
tough, long-wearing and highly resistant to grease and oil. Entirely non-metallic—can't score.

Rigid Heel—
made of a dense resin-bonded fabric to insure a press fit in the packing recess.

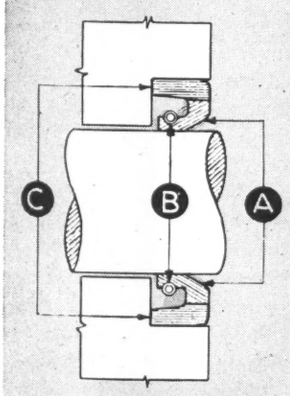
Flexible Lip—
an integral part of the seal. Makes possible accurate control of pressure against shaft by means of self-adjusting garter spring.

Large Bearing Area—
reduces wear on shaft to a minimum.

Self-Adjusting Garter Spring—
permits accurate control of pressures and provides a positive contact with shaft at all times. Special spring stock is available for extreme corrosive conditions.

THIS new J-M "Clipper Seal" offers distinct advantages both from the standpoint of machine design and protection to bearings in service.

Its one-piece precision-made body, concentrically molded and non-metallic in construction, permits liberal machining tolerances. Its simple, compact shape makes possible a light flange section that effects compactness of machine design.



Here's how it works:

The flexible lip (A) is held in light but firm contact with the shaft by means of the garter spring (B). Pressure on shaft is carefully pre-determined to minimize wear, yet effectively seal against leakage. The rigid heel (C) provides a press fit in the cavity, assuring a tight lubricant-retaining seal at this point also.

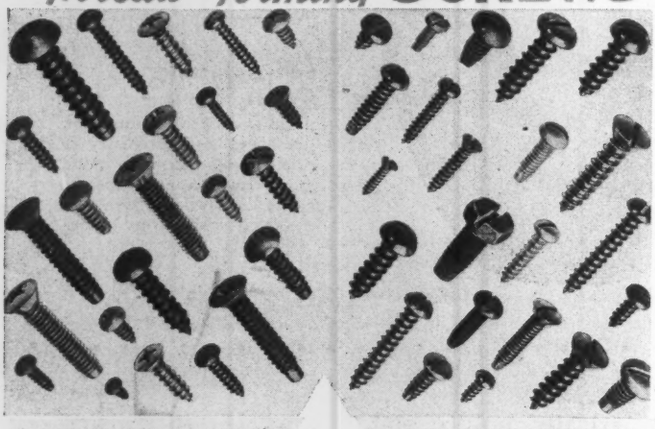
In service, these features of the J-M Clipper Seal provide a positive lubricant-retaining, dirt-excluding seal . . . automatic in its operation . . . adaptable to a wide range of conditions . . . and highly resistant to most forms of corrosion.

Johns-Manville Clipper Seals are made in sizes for shafts from 1 5/16" to 37" diameter, in both endless and split types. Special designs are available where unusual temperature, pressure or chemical conditions require. For further details, write Johns-Manville, 22 East 40th Street, New York 16, New York.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville ***PACKINGS & GASKETS***

SPEED UP
YOUR
ASSEMBLING
with
HOLTITE
SHEET METAL
"Thread-Forming" SCREWS



Speed Nuts are Speedier
when used with HOLTITE
"Thread-Forming" Screws

By cutting perfect mating threads in any material as they are turned in drilled or molded holes, these hardened speed fastenings eliminate the time, cost and hazards of tapping operations. Setting up tighter they resist the loosening effects of vibration and insure strong, enduring fastening of parts in your assembly.

Our Engineering Staff will gladly study fastening problems that confront you, and make recommendations for the most efficient solution. Frequently, a Special fastening designed for the specific application, eliminates the part to be fastened by including it in its design. Thus, an extra part is eliminated and a stronger fastening results.

CONTINENTAL
SCREW CO. New Bedford
Mass., U.S.A.

under intense neutronflux must be solved. The health and protection problem must be systematized and simplified. Finally and most important, the basic scientific knowledge must be reduced to engineering practice. This all requires a comprehensive research - development - engineering approach with long-range objectives.

Development programs directed toward the use of nuclear energy for power production should be undertaken by all branches of the power industry with governmental support, but not in the anticipation of quick application in competition with conventional fuels. A large amount of fundamental research in nuclear and related fields also will have to be done in support of the long-range program. Since much of the equipment required in nuclear research today, such as cyclotrons and betatrons, is large and expensive, it will be necessary for the government to support the fundamental program too, if it is to progress at an adequate rate.

We have, during the war, largely used up our accumulated surplus of basic knowledge of the nucleus. The dividend was the atomic bomb. We must, without further delay, restore this surplus in preparation for the important peacetime job for the nucleus-power production.

Cooperative Effort Essential

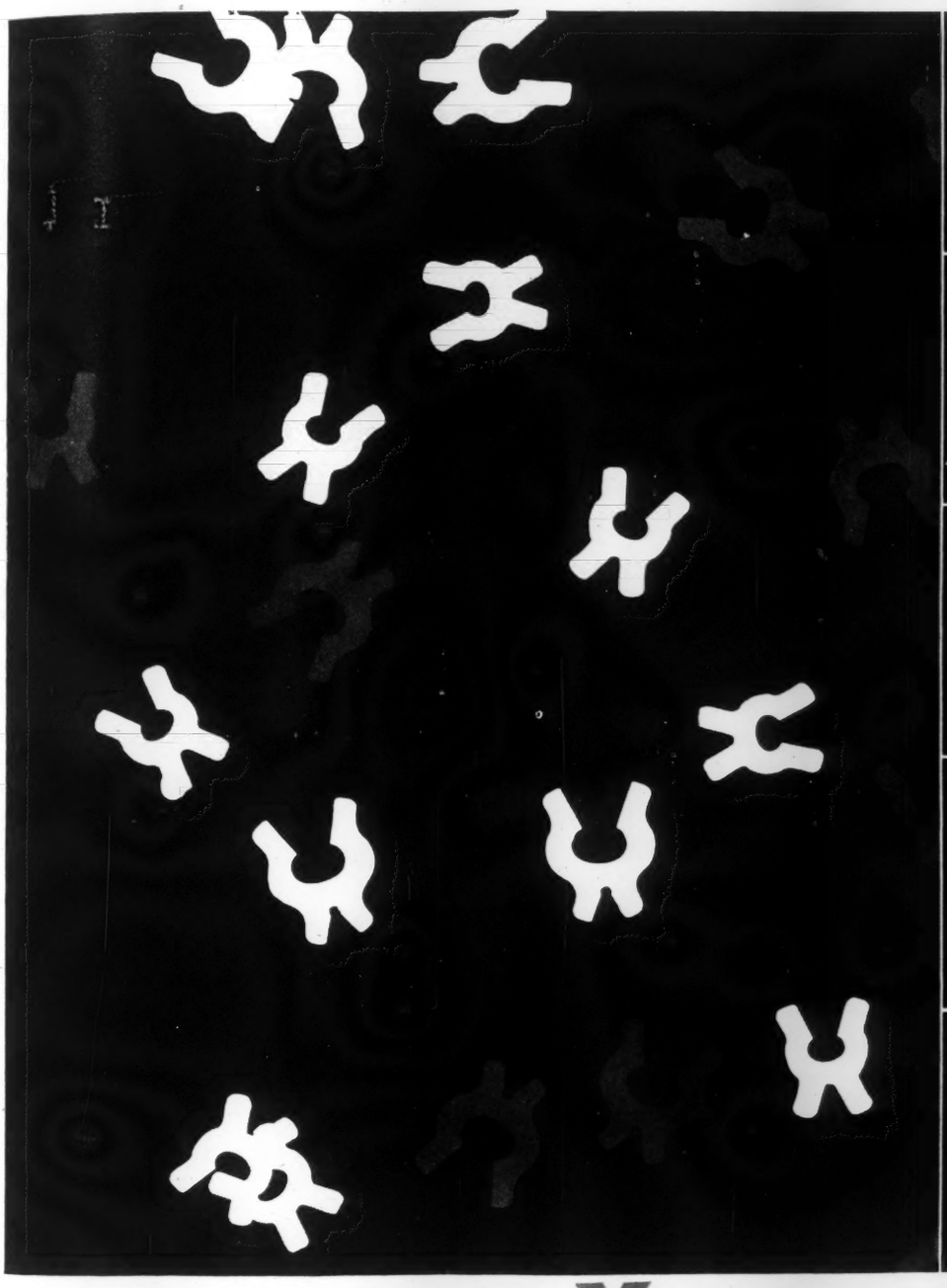
The development of economical atomic power is not a simple extrapolation of knowledge gained during the bomb work. It is a new and difficult project and great effort will be required to reach a satisfactory answer. Needless to say, it is vital that atomic policy legislation now being considered by Congress should recognize the essential nature of this peacetime job and not only permit but encourage the cooperative research-engineering effort of industrial, government and university laboratories for this task.

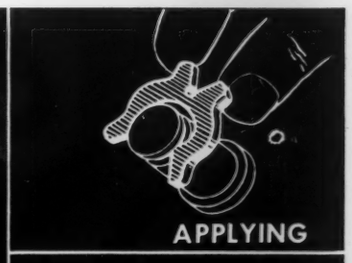
Every scientist knows that the sure way to court trouble is to predict the scientific future. Bold predictions usually fall short of the long-range realization. For that reason, which can be illustrated by many examples, I doubt if the long-range potentialities of the nucleus are clearly foreseen by anyone.

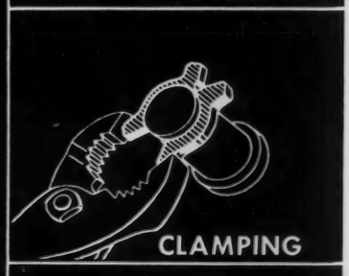
In the immediate future the techniques and materials of nuclear reactions will be a tremendous stimulus to research in physics, chemistry, metallurgy, and the biological sciences. I doubt, however, if these things, important as they are, can be compared in importance with the ultimate possibilities of nuclear power. I feel sure that the outline of the atomic age of the future is perceived as dimly now as was the shape of the electronic age when the Edison effect was first discovered.

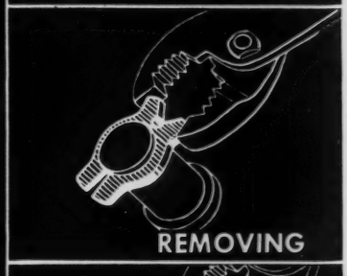
The nuclear reactions in a pile lie chiefly in the energy range below 10 million electron volts. Until recently the most energetic laboratory radiation, from the cyclotron, did not exceed 40 million electron volts. We are now exploring in Schnectady a whole new energy range between 50 and 100 million electron volts with our big betatron. We must learn how to generate the still higher energy particles of the cosmic rays—up to 10^8 million electron volts—for they will unlock new domains in the nucleus.

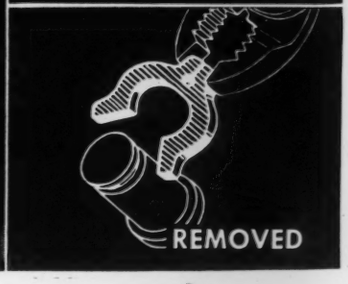
Here is a vast unknown to explore—an endless frontier. The goal of nuclear research is the vast storehouse of energy in the atom, 10 billion kilowatt-hours per pound. Today we obtain by fission only one-thousandth of this potential. Someday we will obtain more!











AEROQUIP X WASHERS*

1. EFFICIENT, ECONOMICAL. 2. Quick positive c supports greater thrust load. 4. Quick, easy remo Aeroquip X-Washers are available for the followi and 13/32". Other diameters on special request.

AEROQUIP FIRSTS

Self-Sealing Couplings
Detachable Hose Fittings
Hydrofuse

* **Another Aeroquip First**

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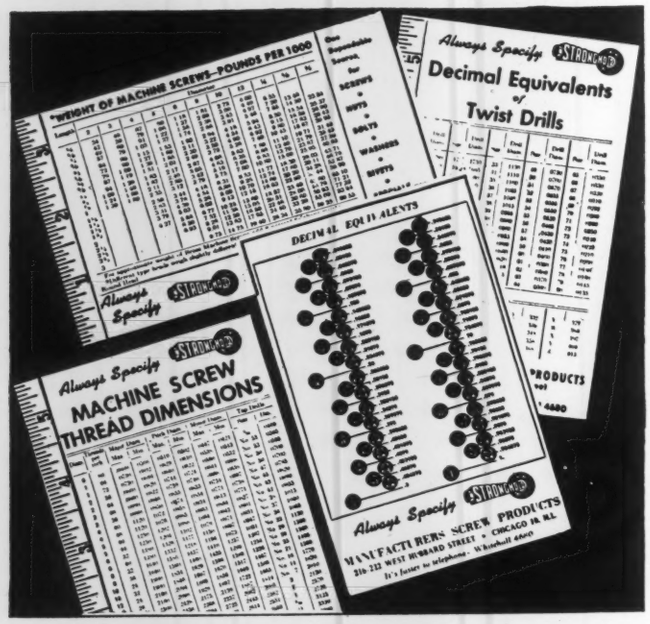

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MANUFACTURERS SCREW PRODUCTS

BUSINESS AND SALES BRIEFS

ASSOCIATED with the company since 1930, J. J. Daggon has been made vice president in charge of sales of Leland Electric Co., Dayton 1, O. Prior to his appointment he was assistant to the vice president in charge of engineering.

♦

Formerly district manager in Washington, D. C., Robert A. Parks has been named general sales manager of the Jessop Steel Co. Mr. Parks will now make his headquarters at the home office of the company in Washington, Pa.

♦

Phillips Control Corp. of Chicago has acquired the design, manufacturing and selling rights of relays formerly made by G-M Laboratories Inc. This new line of relays will be offered under the trade name Phil-trol.

♦

With headquarters at 401 Broadway, New York, Porter Turner has been made field engineer in the New York and Philadelphia territory of Alliance Mfg. Co., Alliance, O. Prior to his service with the Merchant Marine, Mr. Turner had been a sales engineer with the company for eight years.

♦

To serve as its representative in western Pennsylvania and eastern West Virginia, Precision Welder & Machine Co., of Cincinnati, O., has appointed the Weber-Semmer Co., 5108 Liberty Ave., Pittsburgh 24. Thomas P. Moran has been named Detroit district manager for Precision Welder company, with headquarters at 6432 Cass Ave.

♦

Election of G. C. Miller as vice president and general sales manager of the Thermoplastic Department has been announced by Bakelite Corp.

♦

Sales engineer in the Chicago district since 1937, G. M. handler has been named assistant to the vice president in arge of sales of Carboloy Co. Inc. Mr. Chandler will devote major part of his time to sales analysis and market research rk in the fields of carbide tools, dies, and wear resistant parts. E. Weldy, formerly assistant to the vice president, has been pointed manager of distributor sales. He will supervise dily all sales activities through the company's distributor anization.

♦

Construction has been started on an addition to its McCrack- Street plant, according to a recent announcement by Kay- Engineering Corp., Muskegon, Mich.

♦

ffices in the French Bldg., 45th St. & Fifth Ave., New York, been established by B. F. Goodrich Chemical Co. Perel includes: O. E. Isenburg and R. F. Dettelbach, sales sentatives for Geon polyvinyl materials; Jack H. Rines,

To help you lower product costs, improve product performance for 1947 production... *let us help you do your Fractional H.P. motor engineering NOW....*

You can take an effective step towards avoiding competitive disadvantages next year. Consult with our engineers *NOW* if you plan to use production-run quantities of small motors (1/500 to 1/15 H.P.) in your 1947 products. It will help ensure delivery of motors to your assembly lines on time. And your cost and performance problems will be solved during the earliest stages of planning to your best advantage. Our skilled, experienced factory engineer will meet with your engineers in your own plant. In answering your questions on small motor design, engineering and production, he'll apply the latest and most complete technical information. Write today, describing briefly your product design plans.

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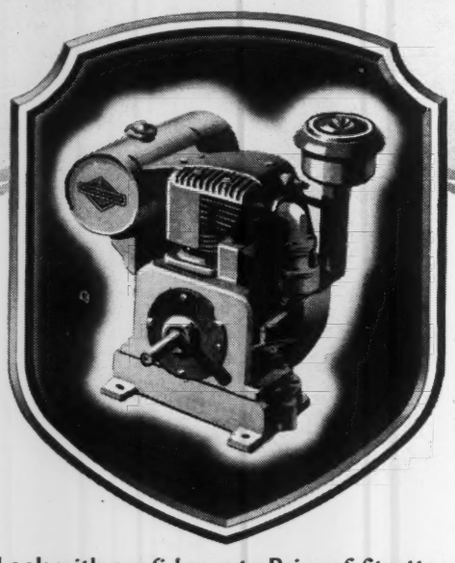
Pilot Fractional H.P. MOTORS & BLOWERS

BRIGGS & STRATTON ENGINES

As Always - Foremost in Value and Performance



Look with confidence to Briggs & Stratton 4-cycle, *Air-Cooled* engines — "preferred power" in all fields — for the latest and most advanced developments for every application requiring ⅔ to 6 H. P. The Briggs & Stratton organization—with its concentration of technical knowledge, modern plants, equipment, and skilled workers—builds gasoline engines which are more than equal to today's most exacting power and performance requirements. You can expect *and get* more value per dollar if the appliances, farm machines or industrial equipment you buy, sell or make are powered by Briggs & Stratton.

BRIGGS & STRATTON CORP., Milwaukee 1, Wis., U.S.A.

Air-Cooled Power

Philadelphia reclaimed rubber sales; and Roger Bascom, Hycar synthetic rubber sales. Also announced by Goodrich is the opening of a Chicago office in Room 1119, Field Bldg. Clyde Segner, handling Geon sales in that territory, has been placed in charge of the new office.

♦

According to a recent announcement by St. Regis Paper Co., New York, the sales operation of the Panelyte division will be conducted through the company's wholly-owned subsidiary, St. Regis Sales Corp.

♦

Rustless Iron & Steel Division of American Rolling Mill Co. has named G. D. Moomaw as general manager. Frank Buffo, associated with the company since 1930, has been made manager of stainless bar and wire sales of the division.

♦

Construction of new steel warehousing buildings in Cleveland has been planned by United States Steel Supply Co., subsidiary of United States Steel Corp. To be built on a nine-acre industrial tract on Bessemer Ave. in southwest Cleveland, the new structures will more than double existing facilities which will be abandoned upon completion of the plant.

♦

Announced by Allied Control Co. Inc. are the appointments of J. S. Speer as eastern sales manager and Hugh M. Noble as western sales manager, with headquarters at Chicago. E. A. Taylor, formerly with General Electric Co., has joined the company as general sales manager.

♦

Buffalo Machinery Co. Inc. has named Tool Service for Industry, 140 North Dearborn St., Chicago, as distributor for its torque control couplings. Operated by Thomas C. Barber, the newly appointed distributor will cover the territory of northern Illinois, southern Wisconsin, northwestern Indiana, and the eastern portion of Iowa.

♦

Connected with the company in a sales capacity since 1923. Louis M. Brown has been appointed to the newly created post of general sales manager of The Eberhard Faber Pencil Co., Brooklyn, N. Y.

♦

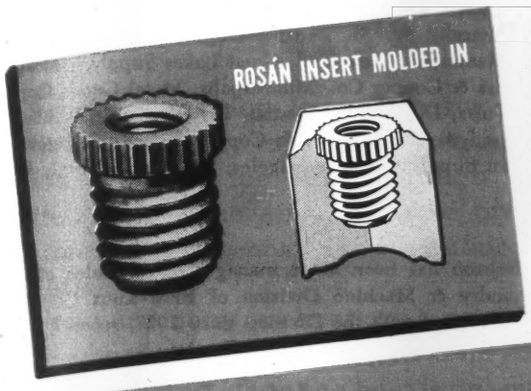
With offices at 75 West St., New York, T. L. Lee has been named district manager of Agaloy Tubing Co. of Springfield, O., and will cover the New Jersey, New York and New England areas. Prior to his appointment Mr. Lee had been assistant manager of tube sales for Peter A. Frasse Inc.

♦

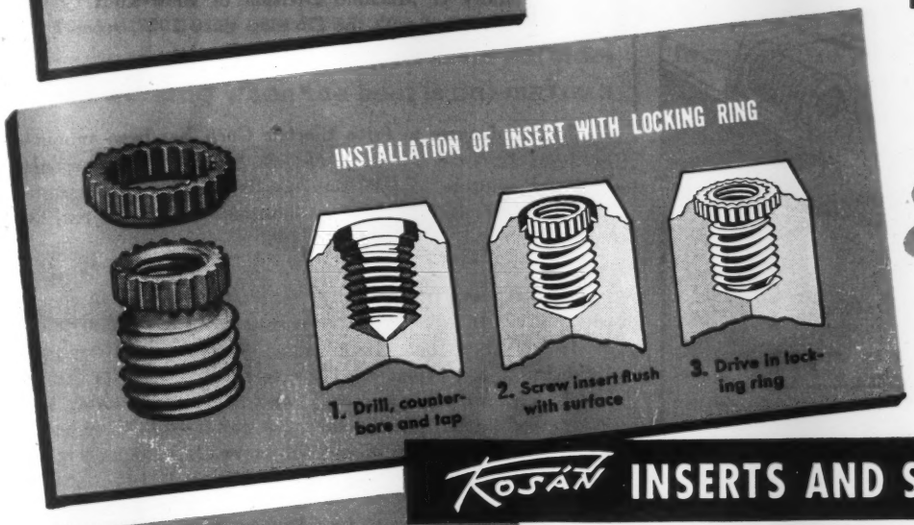
Formerly Pittsburgh district sales manager, Max J. Pischke has been promoted to the position of manager of warehouse sales of Allegheny Ludlum Steel Corp.

♦

Appointment of the following supply firms as distributors of its industrial fittings and tube bending equipment has been announced by Parker Appliance Co., Cleveland: Whitehead Metal Products Co., New York, Boston, Buffalo, N. Y., Newark, N. J., and Philadelphia; Williams & Co., Pittsburgh, Cleveland and Cincinnati, O.; A. E. Borden Co., Boston; Carey Machine & Supply Co., Baltimore, Md.; Louis H. Hein Co., Ardmore,

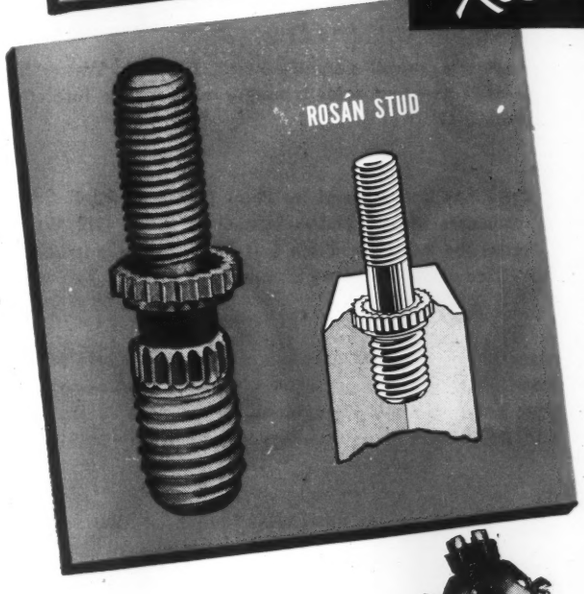


NOW "National" offers High Tensile Fastenings for


INSTALLATION OF INSERT WITH LOCKING RING
1. Drill, counterbore and tap
2. Screw insert flush with surface
3. Drive in locking ring

Soft Metals and Plastics

Rosán INSERTS AND STUDS STAY TIGHT



The tendency of fastenings to work loose under vibration or torque is overcome by the Rosán Locking System for inserts and studs, now made by National Screw & Mfg. Co.

Rosán Fasteners may be molded in, or easily installed in parts after forming. The entire design is based on a simple serrated ring which locks either an insert or stud in position, and so prevents loosening or turning by any stresses on the connecting unit.

Securely locked in place, a Rosán Fastener gives a long wearing, high strength tapped hole or a firmly anchored projecting stud. It can be removed by drilling without disturbing the parent material.

Send for samples and full information on these revolutionary new fasteners, already adopted by leading aircraft companies and other industries.

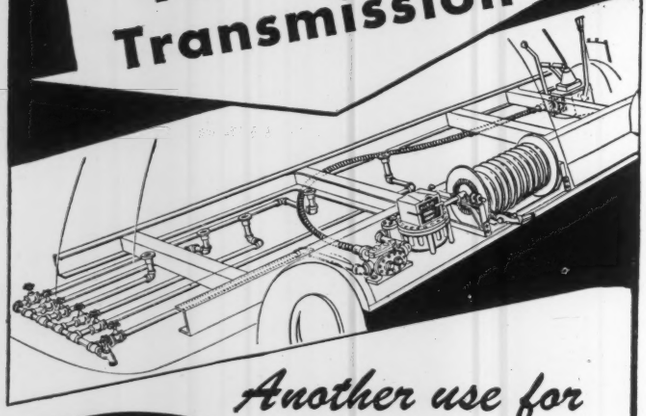
(Patents issued and pending, U. S. A. and foreign countries)

National HEADED AND THREADED PRODUCTS

THE NATIONAL SCREW & MFG. CO., CLEVELAND 4, O.

STOW Flexible Shaft

For Power Transmission



Another use for STOW FLEXIBLE SHAFT

An oil truck chassis equipped with STOW Pump Drive. Power take-off from transmission operates pump at side of frame.

● For power transmission between misaligned members, STOW Flexible Shaft is proving its merit in hundreds of new installations. Ease of service, added safety, minimum maintenance, ease of installation, and freedom from lay-ups—all these considerations weigh heavily in favor of STOW Flexible Shaft Power Transmission in the example illustrated above.

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- ADAPTABILITY TO *YOUR* PROBLEM
- ECONOMICAL INSTALLATION
- LOW MAINTENANCE COSTS

SEND US YOUR PROBLEM!

Stow engineers, without cost or obligation, will study any problem you may submit in power transmission . . . or in any of the other functions where Flexible Shafting is better, such as remote control or indications. We'll send our findings to you—for your decision!

There's also a STOW Flexible Shaft to handle almost any problem in REMOTE CONTROL or INDICATION.

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Position.....

Company.....

Street.....

City..... State.....

Pa.; Squier-Schilling & Skiff, Newark, N. J.; Somers-Fitler & Todd, Pittsburgh; W. M. Pattison Supply Co. and Strong-Carlisle & Hammond, Cleveland; Great Lakes Supply, Chicago; Vincent Brass & Copper Co., Minneapolis; Metal Goods Corp., St. Louis, Tulsa, Dallas and Houston, Tex.; General Machinery & Supply and American Brass & Copper Co., San Francisco; Metropolitan Supply Co., Los Angeles; and Eagle Metals Co., Seattle.

♦

A. L. Ralston has been made manager of roll sales of the Lewis Foundry & Machine Division of Blaw-Knox Co. He has been associated with the Division since 1927, recently having served as assistant manager of roll sales.

♦

Change of name to Price Electric Corp. has been announced by Price Brothers Co. of Frederick, Md., manufacturer of relays and controls. L. V. Roughan is president and treasurer, and Dr. C. Frank Miller is in charge of engineering and sales.

♦

Pittsburgh representative for the company prior to the war, R. H. Munn Jr. has been made manager of the Pittsburgh office of Ampco Metal Inc., Milwaukee. With headquarters at 732 Frick Bldg., Mr. Munn will serve as field engineer in the Pittsburgh territory. W. J. Nebel, who had been working in the Wisconsin district, has assumed the duties of field engineer in the Newark, N. J., district and will make his headquarters at the company's office at 1060 Broad St., Room 521.

♦

According to a recent announcement, Fred C. Walter has been appointed assistant sales manager of Formica Insulation Co., Cincinnati, O.

♦

E. A. Price has been named by Penn Electric Switch Co. to serve as manager of the Dallas branch office at 302 Wilson Bldg. Before the war, Mr. Price had been a sales engineer at the home office of the company at Goshen, Ind.

♦

Construction of a new mechanical research laboratory at New Providence, N. J., has been started by Air Reduction Sales Co., New York. This will augment the position of the company and its subsidiaries in the oxyacetylene industry.

♦

Formerly a salesman at the Dallas branch of Wagner Electric Corp., Forrest G. Wilson has been named manager of the Indianapolis branch. H. F. Zahn, previously manager of the Atlanta branch, has been appointed manager of the Philadelphia branch. Succeeding him at Atlanta is C. G. Jackson, who had been manager of the Boston branch. Succeeding Mr. Jackson in turn is J. K. Miller, formerly a New York branch salesman.

♦

Techtmann Industries Inc. has moved from 828 North Broadway to 714 West Wisconsin Ave., Milwaukee 3.

♦

Celebration of its twenty-fifth anniversary has been announced by the R-B-M Division of Essex Wire Corp., manufacturer of manual and magnetic controls for automotive, industrial, communication and electronic use. Recently the division opened sales offices at 14310 Woodward Ave., Detroit; at 607 Winter Bank Bldg., Dayton, O.; and at 1064 Union

BETTER SURE THAN SORRY

According to olden legend Icarus flew too near the sun, only to spin in when his wings failed to stand the stress at high temperature. Here was an early case of serious trouble due to misplaced confidence in materials.

There are many applications for steel nowadays where creep strength (the ability of steel to keep working when the heat is on) makes a tremendous difference. Molybdenum steels, being noted for their creep strength, are economical preventives of hign temperature trouble.

Icarus had no accurate data on materials to guide him. A wealth of tested, practical facts about Molybdenum steels for elevated temperature service is available on request for today's engineers and designers.

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CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

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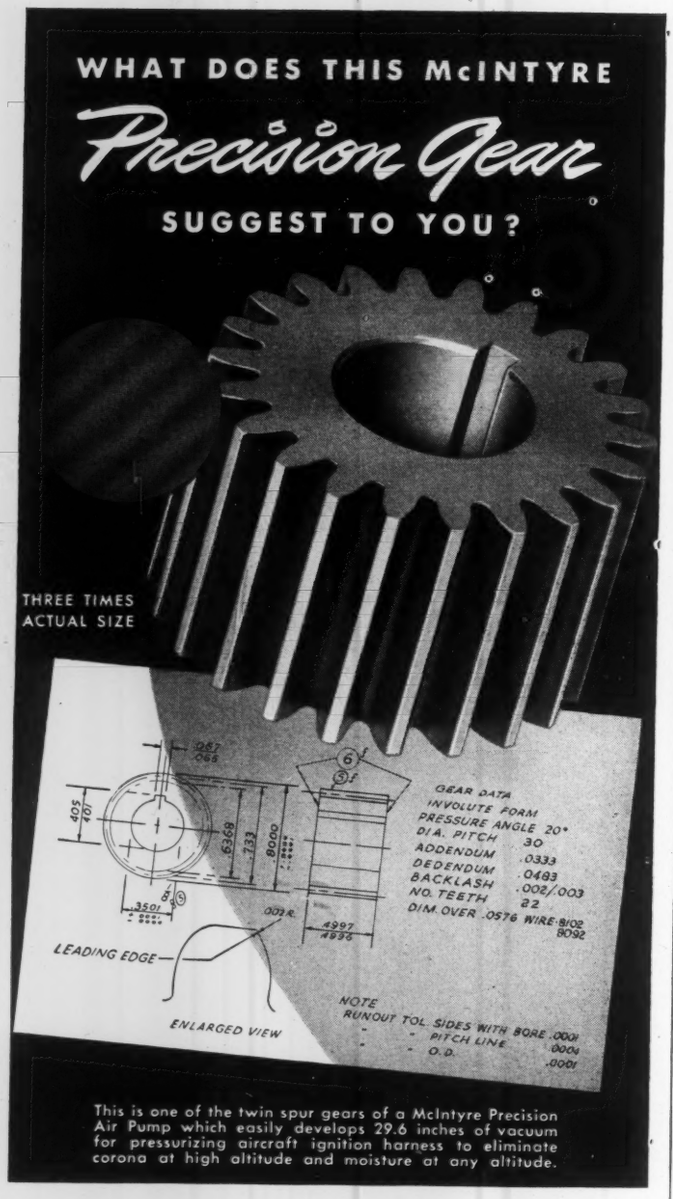

This is one of the twin spur gears of a McIntyre Precision Air Pump which easily develops 29.6 inches of vacuum for pressurizing aircraft ignition harness to eliminate corona at high altitude and moisture at any altitude.

HOW TO GET BETTER GEARS AT ORDINARY PRICES

With machining methods capable of making surfaces flat to one light band and holding vital dimensions to plus or minus .000025", The McIntyre Co. applies tool-room tolerances to the mass production of spur gears.

That's why it is routine instead of special production when the illustrated gear has its sides lapped within .00005" of parallelism . . . its hole and O.D. ground to .0001" tolerance and runout . . . its teeth shaped and shaved to a pitch line runout of .0004".

For spur gears up to 10" O.D., to tolerances in tenths and split tenths in any material, specify McIntyre Precision Gears. Submit specifications for estimates — today. The McIntyre Co., 300 Riverdale Ave., Newton 58, Mass.

THE McINTYRE CO.
(FORMERLY ZENITH ASSOCIATES)
PUMPS AND FLUID MOTORS

THE ULTIMATE IN PRECISION IDENTIFIED BY THE LIGHT BAND

Commerce Bldg., Cleveland. At the Detroit office G. L. McGowan is in charge of industrial sales, and T. D. Reedy is in charge of automotive sales. H. G. Horton is in charge of the Dayton office, and J. A. Fiske, the Cleveland office.

♦

Connected with Owens-Illinois Glass Co. since 1933, Joseph W. Parks has been appointed manager of the Plastics Division.

♦

Addition of three new divisions to its industrial engineering divisions has been announced by General Electric Co. These are: Power Electronics Division, Materials Handling & Testing Equipment Division, and Rubber & Printing Division. Also announced is the reorganization of the Machinery Division, headed by H. W. Poole.

♦

Following the resignation of Dwight E. Adams, the Heppenstall Co. has appointed S. J. Mergenhagen as district representative in Philadelphia, with headquarters at Room 1052, Drexel Bldg.

♦

A new modern plant for the processing of plastics will be constructed near Marietta, O., by The B. F. Goodrich Co. of Akron, O. The company recently acquired the assets of the Hycar Chemical Co. in Akron, world's largest private producer of Nitril oil-resistant types of synthetic rubber. New Hycar headquarters will be in the company's main office in Cleveland, but production will continue at the Akron plant.

♦

Recently announced by Dayton Rubber Mfg. Co. is the appointment of Eugene Dolan to the New York City sales office. Prior to his service in the Marine Corps, Mr. Dolan had been associated with Standard Brands Corp.

♦

Central States Engineering Corp. has been organized recently at 4612 Woodward Ave., Detroit 1, to help any manufacturer with the designing of special machinery, jigs, dies, etc. With more than fifty engineers on its staff, the new organization is equipped to set up processes and methods of manufacture and assist in product development. It was organized by E. M. Beyma, president and general manager; John Allmon, vice president and chief engineer; and Frank Querry, secretary-treasurer.

♦

Appointment of Max Miller of Detroit as sales manager has been announced by The Duraloy Co., Scottdale, Pa. Previously Mr. Miller was associated with the company's representative, F. B. Cornell & Associates, in a sales engineering capacity.

♦

John G. Barta, of the Milwaukee district office of Allis-Chalmers Mfg. Co., has succeeded William H. Knight, who resigned recently as manager of the Duluth, Minn., branch sales office.

♦

CORRECTION: In an announcement published in the March issue referring to the appointment of James Adair as sales engineer of Star Electric Motor Co., to cover the New Jersey industrial area, the address of the company was erroneously given as Providence, R. I. This should have read Bloomfield, N. J.

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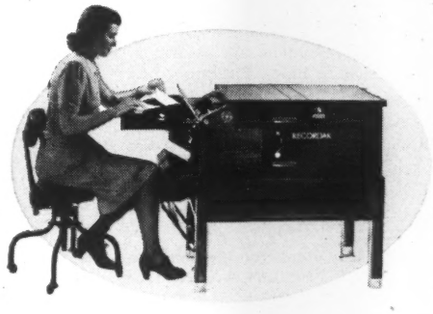
Filing war documents on Recordak microfilm makes them instantly available . . . releases file space for current records



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We'll be at Booth 323 National Plastics Exposition!

If you are going to be in New York any time from April 22nd to 27th, plan to visit our booth at the National Plastics Exposition, Grand Central Palace —see first-hand the type and quality of work we do on both molded plastic and molded rubber parts. Members of our engineering staff will be there to answer your questions. Taylor Manufacturing Co., 3090 W. Meinecke Ave., Milwaukee 10, Wis.

TAYLOR OF MILWAUKEE

CUSTOM MOLDERS OF HI-EFF PLASTIC AND RUBBER PARTS

Meetings and Expositions

April 8-12—
American Society of Tool Engineers. Fifth exposition to be held at Public Auditorium, Cleveland. Additional information may be obtained from headquarters of the society at 1666 Penobscot Bldg., Detroit 26.

April 10-13—
Electrochemical Society Inc. Spring congress to be held at Hotel Tutwiler, Birmingham, Ala. Colin G. Fink, 3000 Broadway, New York 27, is secretary.

April 15-18—
National Warm Air Heating & Air Conditioning Association. First annual warm air heating conference to be held at the College of Applied Science of Syracuse University, Syracuse, N. Y. Geo. Boeddener, 145 Public Square, Cleveland, is managing director.

April 22-27—
Society of the Plastics Industry Inc. First national plastics exposition to be held at Grand Central Palace, New York 17. W. T. Cruse, 295 Madison Ave., New York 17, is executive vice president.

April 27-May 19—
CANCELLATION: The Products of Tomorrow Exposition, which was scheduled to be held at the above dates at the Chicago Coliseum group of buildings, Chicago, has been indefinitely postponed.

April 28-May 1—
American Ceramic Society Inc. Forty-eighth annual meeting to be held at Hotel Statler, Buffalo. Ross C. Purdy, 2525 North High St., Columbus 2, O., is general secretary.

May 6-7—
Association of Iron & Steel Engineers. Spring conference, sponsored by the rolling mill committee, to be held at Congress Hotel, Chicago. Additional information may be obtained from headquarters of the society at 1010 Empire Bldg., Pittsburgh 22.

May 6-10—
American Foundrymen's Association. Foundry congress and show to be held at Public Auditorium, Cleveland. Wm. W. Maloney, 222 West Adams St., Chicago 6, is secretary.

June 2-7—
Society of Automotive Engineers Inc. Summer semiannual meeting to be held at French Lick Springs Hotel, French Lick, Ind. John A. C. Warner, 29 West 39th St., New York 18, is secretary and general manager.

June 3-5—
American Gear Manufacturers Association. Thirtieth annual meeting to be held at The Homestead, Hot Springs, Va. Newbold C. Goin, Empire Bldg., Pittsburgh 22, is executive secretary.

June 3-6—
American Society of Mechanical Engineers. Aviation Division meeting to be held at Los Angeles. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York. C. E. Davies is secretary.

June 12-15—
American Society of Mechanical Engineers. Oil and Gas Power Division meeting to be held at Milwaukee. Additional information may be obtained from headquarters of the society at 29 West 39th St., New York. C. E. Davies is secretary.

June 17-20—
American Electroplaters Society. Annual convention to be held at Hotel William Penn, Pittsburgh. Additional information may be obtained from headquarters of the society at 93 Oak Grove Ave., Springfield, Mass.

Instant TEMPERATURE DETECTION*

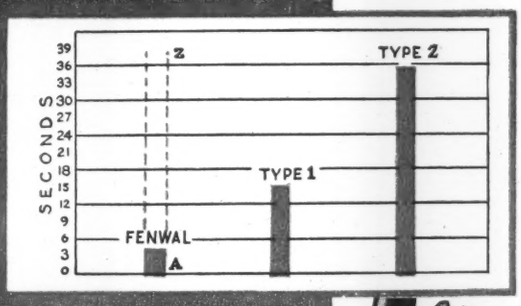
What temperature detection time best fits your product? The fast response of the Fenwal Thermoswitch allows you to engineer into your product the optimum speed of detection—from A to Z. Compare the response time of the Thermoswitch with other thermostats.

Chart shows the time interval required for a Fenwal Thermoswitch to change 10°F. when subjected to a 20° change in temperature. Compare this performance with that of Type 1 and Type 2 thermostats. Proper application can modify this response time to any value desired, from A to Z.

Study the advantages of Fenwal Thermoswitches before making any commitment, for the Thermoswitch has many advantages which are not found in other types of temperature control units . . . the unique principle of operation of Fenwal Thermoswitches permits extreme accuracy combined with rugged yet compact construction.

Send for your copy of the Thermotechnics booklet which includes "Fourteen Facts in Fenwal's Favor."

RESPONSE TIME CHART



CARTRIDGE THERMOSWITCH

CROSS SECTION CARTRIDGE THERMOSWITCH

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3.—Short heat transfer path
4.—Small temperature differential
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6.—Enclosed assembly
7.—Minimal vibration effects
8.—Directly responsive to radiant heat
9.—Rugged construction
10.—Adjustable over wide temperature range
11.—Minimum size
12.—Tamper-proof and sealed
13.—Uniform sensitivity over adjustable temperature range
14.—Readily installed

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